CORE
Metadata, citation and similar papers at core.ac.uk
Provided by KhartoumSpace

University of Khartoum

Faculty of Engineering & Architecture

Civil Engineering Department

Sanitation Systems in Khartoum State

(Evaluation and Pollution Impact)

By:

Mohamed Omer Albesheer Ahmed

A Thesis Submitted as a Partial Fulfillment for the Degree of

M.Sc. in Sanitary Engineering

Supervised by

Dr. Mohamed Ahmed Adam Khadam

October.2007

ACKNOWLEDGEMENT

I would like to express my sincere appreciation to Dr. Mohammed Ahmed Adam Khadam for his sustained help and his encouragement.

I also extend my sincere thanks to the family of Sanitary Engineering laboratory at Khartoum University.

Grateful thanks to Mr. Baharaldeen Abdullah who took a lot of time in language checking up.

Special thanks are due to Mohammed mudathir (hamam) who contributed in questionnaire distribution and community survey.

My warmest gratitude for my family, friends and my colleagues for active support and encouragement.

ملخــص

تستمد دراسة وسائل الاصحاح والتخلص من الفضلات والنفايات أهميتها بما تشكله من تهديد على صحة الافراد والمجتمعات وارتباطها الوثيق بمشاكل التلوث.

الهدف من هذه الدراسة هو تقييم وسائل الاصحاح بولاية الخرطوم، ومدى تأثيرها على جودة المياه السطحية والجوفية. استندت الدراسة على أخذ عينات من المياه السطحية (النيل الأبيض، النيل الأزرق، ونهر النيل)، وعينات من آبار التخلص المنزلية وحللت معملياً. كما صمم استبيان لمعرفة العلاقة بين وسائل الاصحاح والعوامل الاجتماعية والاقتصادية والصحية.

أوضح تحليل عينات المياه السطحية وجود قيم عالية للأكسجين الحيوي المطلوب في منطقتين، بما يعطي مؤشر للتلوث. ووجد أن قيم الأمونيا فوق المتوقع في بعض العينات. وسجلت قيم عالية لتركيز الزيوت والدهون في بعض المواقع.

أوضحت نتائج تحليل عينات آبار التخلص أن هذا النظام يمثل تهديدا للمياه الجوفية لاحتواء هذه الأبار على تراكيز عالية من الأمونيا والتي يمكن أن تتحول بفعل الباكتيريا الى نتريت ونترات، وهذا يعني امكانية حدوث تلوث كيميائي للمياه الجوفية.

بالرغم من أن أول شبكة صرف صحي بمنطقة الدراسة انشئت في العام 1954، إلا أنها لا تغطي الآن أكثر من 1.4% بينما يستخدم الغالبية العظمى مرحاض الحفرة بنسبة 73% يليه حوض التحليل وبئر التخلص بنسبة 21% والبقية 3.8% تشكلها مجموعة من طرق الإصحاح البائسة.

مرحاض الحفرة الغالب استخدامه هو مرحاض الحفرة التقليدي (62 %)، ويستخدم أنبوب التهوية بنسبة 38%، ووجد أن 12% من مراحيض الحفرة حفرت إلى مستوى الماء تحت السطحي مما يشكل خطرا مباشرا على المياه الجوفية (تلوث كيميائي).

توصلت الدراسة إلى أن مشاكل الرائحة والذباب والحشرات التي تواجه مرحاض الحفرة تتزايد مع ارتفاع محتويات المرحاض، ويقلل أنبوب التهوية هذه المشاكل بما يقارب 11% منها، إلا انه يتوقع أن تزيد هذه النسبة في حال وضع الأنبوب بالصورة العلمية الصحيحة.

وجدت الدراسة ان استهلاك الماء يرتبط بصورة واضحة بوسيلة الاصحاح المستخدمة، إذ يبلغ متوسط استهلاك الماء لمستخدمي مرحاض الحفرة حوالي 42 لتر للفرد في اليوم، ولمستخدمي نظم حوض التحليل حوالي 67 لتر للفرد في اليوم، بينما يصل إلى 121 لتر للفرد في اليوم لمستخدمي شبكة الصرف الصحي، كما يرتبط استهلاك الماء بالمستوى التعليمي بصورة واضحة.

أكدت الدراسة أهمية التنسيق بين مشاريع المياه من جانب ومشاريع الصرف الصحي ووسائل الاصحاح من جانب آخر. كما أكدت أهمية وجود برامج مراقبة لمصادر تلوث المياه الجوفية والسطحية.

ABSTRACT

The Importance for evaluating sanitation systems, and wastes disposal methods, coming from the fact that: the health of persons and communities are usually affected significantly from any deficiency of the systems.

The objective of this study is to evaluate sanitation systems in Khartoum state, and to assess pollution impacts. Surface water samples had been collected from White Nile, Blue Nile, and river Nile, in order to identify quality of water. To evaluate the impact of septic tanks systems on groundwater, samples from soakaway wells (wells receiving septic tank effluents) had been collected and analyzed. A questionnaires was designed to obtain the relationship between sanitation systems and socio-economic and health factors.

Results of surface water samples analyses showed high values of biochemical and chemical oxygen demand in two locations. Ammonia concentrations in some locations are higher than expected values. Oil and grease are recorded at high concentrations at some locations.

Result of analyses of samples of soakaway wells, indicates that this system forms a threat to groundwater, because of high concentration of ammonia, which may change to nitrate and nitrite. This indicates that chemical pollution to ground water can occur.

Although the first sewer network in the study area started on 1954, this system serves about 1.4% of Khartoum state population, pit latrines forms the common excreta disposal system (73.4%), followed by septic tanks system (21.4%), and the rest (3.8%) includes poor excreta disposal systems.

Pit latrines are of two types. Conventional pit latrine (about 62%); and ventilated improved pit latrines (about 38%). 12% of pits were drilled to water, which may affect the quality of ground water (chemical pollution).

The study indicated that the problems of insects, flies, and odor increase when the content of pit increases. Ventilation pipe decreases these problems by about 11%. Positive influence of ventilation pipe can be increased if the pipe was constructed properly.

There are obvious links between water consumption and sanitation system used. The average of water consumption for pit latrine users equals 42 liter per person per

day, for septic tank systems users equals 67 liter per person per day and for sewer network users reaches 121 liter per person per day. Water consumption has obvious link with education.

The research emphasizes the importance of coordination between water and sanitation projects. Monitoring programs for surface and groundwater pollution loads are highly recommended.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

CHAPTER ONE
INTRODUCTION

1.1 Background

The preamble to the constitution of the world health organization state that "the enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being."[*]

An adequate safe drinking water supply, coupled with an improved sanitation system, is an essential ingredient of healthy, productive life. Dr LEE Jong-wook; Director-General; World Health Organization say that: "Water and Sanitation is one of the primary drivers of public health. I often refer to it as “Health 101”, which means that once we can secure access to clean water and to adequate sanitation facilities for all people, irrespective of the difference in their living conditions, a huge battle against all kinds of diseases will be won"[+]

In most countries, programs for water supply and sanitation have usually been developed separately. Different organizations often administer these programs, and no co-ordination is attempted. This leads to poor environmental conditions where water supply has been provided without drainage, and sometimes, the health of the population affected is put at risk. Even where this dose not happens, the full advantage of complete service is not gained if the water supply component of the package is separated from the waste disposal component. (9)

It is obvious that the authorities in many developing countries have essentially disregarded the problem of excreta disposal. Few urban areas are sewered, and domestic wastes are handled in variety of ways, depending on local conditions, and on the way unofficial practice have developed to suit social and cultural performances. In some few locations, night soil collection systems are operated, either by the authorities or privately, but more generally, on-site disposal is adopted. Septic tanks and cess pits or seepage pits are widely used, even where ground conditions are unsuitable and, inevitably, pollution of ground water and surface water result. Sometimes these systems linked into surface drainage, creating foul condition in

∗http://www.who.int/medicines_technologies/human_rights/en/
+http://www.who.int/water_sanitation_health/factsfigures2005.pdf

streets subject to flooding and generally contributing to surface water pollution. Increasing urbanization has overloaded the natural assimilative capacity of the environment in most large cities in developing countries, and the presence of black-colored, odorous surface water is but one offensive manifestation of the absence of effective sanitation. Squatter or shanty settlements in major cities create particular problems because water supply and sanitation facilities are non-existent and health hazards are high. (9)

In rural areas, population densities are lower and natural assimilation of human wastes has been less damaging in physical terms, but lack of sanitation may have a greater impact on health than in the urban context because people still largely depend on surface water for their potable supply. (9)

1.2 Objectives of the Study

1.2.1 General objectives:

To assess sanitation systems in Khartoum state with emphasis on health problem of rural and urban communities in Khartoum state and propose remedial measures.

1.2.2 Specific objectives:

1- To assess the performance of simple sanitation systems and conventional sewage system in the project area.

2- To identify the coverage of each system in the study area.

3- To determine the impact of wastewater effluent in the quality of ground water and surface water.

4- To identify health influences.

5- To suggest remedial measures for the problems.

CHAPTER TWO

LITERATURE REVIEW

CHAPTER TWO

LITERATURE REVIEW

2.1 Sanitation Technologies

Man has developed various kinds of sewage treatment systems that take advantage of the bacterial action of oxygen in order to enable bacterial utilization. These systems are categorized into two groups:

2.1.1 On-Site Technologies

In which sewage is treated and disposed in-situ by a system normally constructed and maintained by the landlord. Such systems vary considerably in their efficiency, cost, and potential impacts on environment and human's health. The most popular on-site systems are septic tank and disposal wells, aqua privy, pit latrine, cesspool and soak-away pit.

The major On-site sanitation facilities are:

2.1.1.1 Pit Latrine

Pit-latrines are divided into:

2.1.1.1.1 Simple Unimproved Pit Latrine

Conventional pit latrines are the most common sanitation facility used in developing countries. In its simplest form, a pit has three components namely, a pit, a squatting plate (or set and riser) and foundation, and a super structure. The pit is simply a hole in the ground into which excreta fall. When the pit is filled to 1 meter of the surface, the superstructure and squatting plate are removed and the pit filled with soil. A new pit is then dug nearby.

The simple unimproved pit latrine has two major disadvantages: its usually smells, and flies or mosquitoes readily breed in it, particularly when it is filled within 1 meter of the surface. (3)

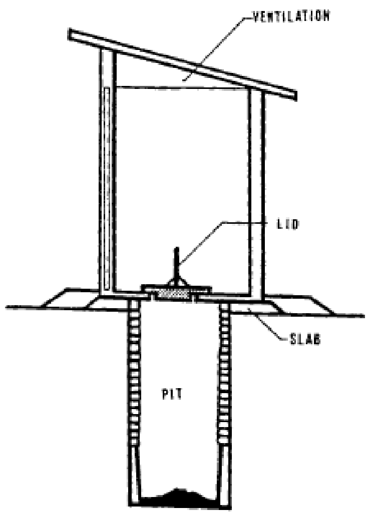


FIG 2.1 SIMPLE UNIMPROVED PIT LATRINE

2.1.1.1.2Ventilated Improved Pit (VIP) Latrine

VIP latrine are a hygienic, low-cost, and indeed sophisticated form of sanitation, have minimal fly and mosquito nuisance, and have only minimal requirements for users care and municipal involvement. The pit is slightly offset to make room for an external vent pipe. The vent pipe should be at least 75 millimeter in diameter (ranging up to 200 millimeter); it should be painted black and located on the sunny side of the latrine superstructure. The air inside the vent pipe will thus heat up and create an updraft with a corresponding downdraft through the squatting plate. Thus any odors emanating from the pit contents are expelled via the vent pipe, leaving the superstructure odor free. The pit may be provided with removable cover sections to allow desludging.

Pit ventilation may also have an important role in reducing fly and mosquitoes breeding. The draft discourages adult flies and mosquitoes from entering and laying eggs. Nevertheless, some eggs will be laid and eventually adult will emerge. If the vent pipe is large enough to let light into the pit, and if the superstructure is sufficiently dark, the adult will try to escape up the vent pipe. The vent pipe, however, is covered by a gauze screen so that the flies are prevented from escaping and they eventually fall back to die in the pit.

Both the vent pipe and gauze screen must be made from corrosion-resistant materials (e.g. asbestos cement, fiberglass, PVC). Little detailed work has been done on the design of the vent pipe; at present it recommended that the pipe diameter should be 75 to 200 millimeters and that it should extend 300 millimeters above the roof; this should be increased to 600 millimeters if the pipe cannot be located on the

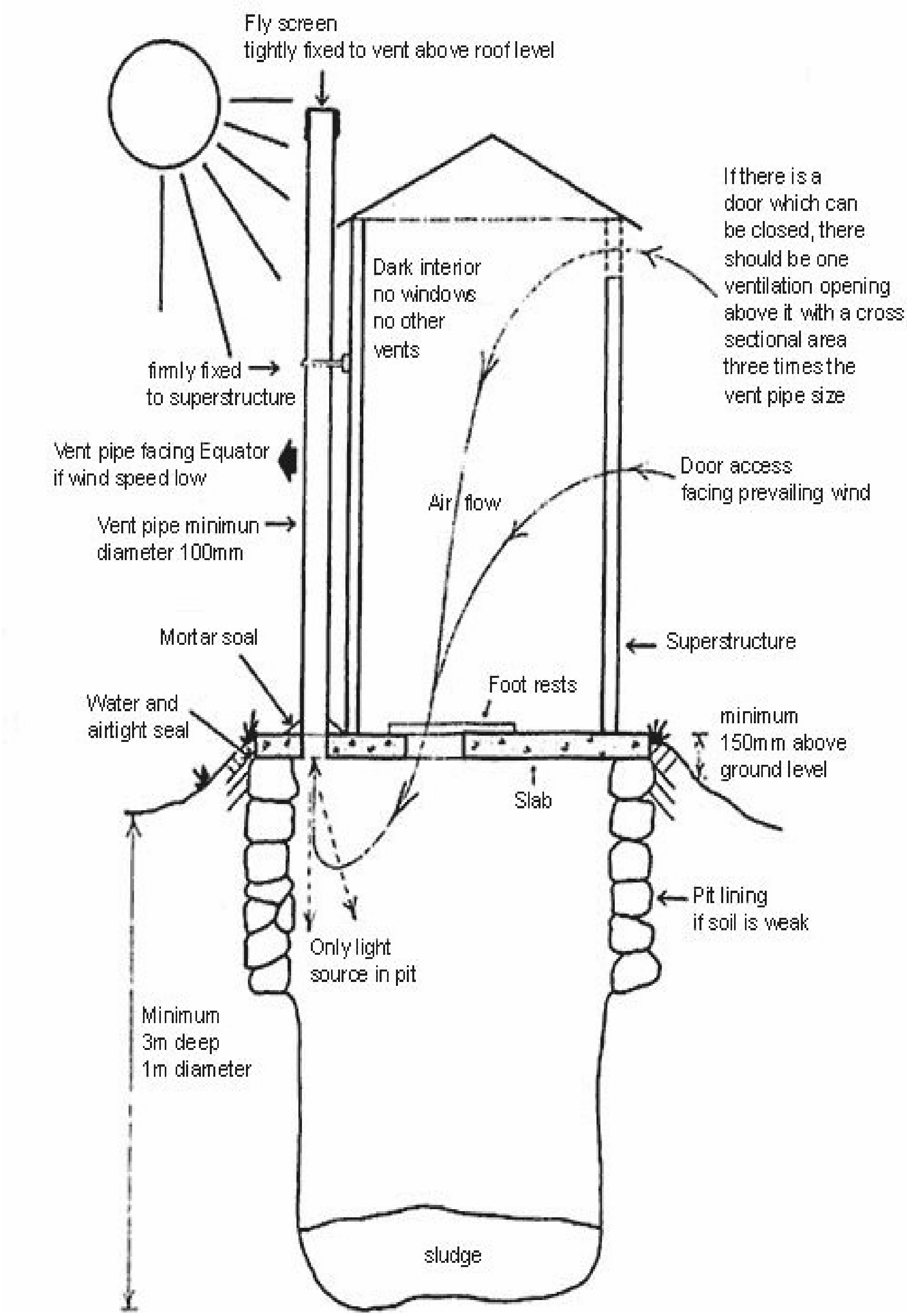


FIG 2.2 VENTILATED IMPROVED PIT LATRINE

sunny side of the superstructure. Local wind patterns and the diurnal variation in ambient temperatures affect ventilation efficiency; theoretical and field work on these aspects is continuing. (3)

2.1.1.1.3 Ventilated Improved Double-Pit Latrine

To eliminate the need to construct very deep pits, to preclude the necessity of construction another latrine once the pit is full, and to facilitate the emptying of the pit where space for replacement latrine does not exist, a double-pit latrine should be used. A VIDP latrine differs in design from VIP only by having two pits. Two pits can be provided by constructing a separation walls in the VIP pit or by constructing two separate pits. Each pit should design to have an operating life of at least one year.

Operation and maintenance of the VIDP is the same as that of the VIP for pit empting. With two pits available, one pit would be used until full and then sealed while the second pit is in use. When the later is almost full, the first pit would be empted and put back into use once more. By alternating, the two pits can be used indefinitely. Because of Excreta in the pit not in use at the time, pathogenic organism will have been destroyed by the time the pit the pit needs to be empted. As a consequence, there is no danger of spreading pathogens and the excavated humus-like materials can be used as a soil conditioner or disposed of without fear of contamination.(3)

2.1.1.1.4 Borehole latrines

An alternative version in areas with deep soil free of stones is the bored hole latrine(9), but this type is not recommended as a household sanitation facility since it is too small (usually only 400 millimeters in diameter and up to 4 meters deep for hand augers) and cannot be ventilated. Borehole latrines thus have a short lifetime (1 to 2 years) and generally unacceptable levels of fly and odor nuisance. Where mechanical augers are available, greater depths and lifetimes can be provided but ventilation is still a problem. (3)

2.1.1.1.5 Reed odorless earth closet (ROEC)

An alternative design for a VIP is the ROEC, in this latrine the pit is completely offset and excreta are introduced into the pit via a chute. A vent pipe is provided, as in the VIP latrine, to minimize fly and odor nuisance. A disadvantage of ROEC, however, is that the chute is easily fouled with excreta and thus may provide a site for fly breeding; the chute therefore has to be cleaned regularly with long-handled brush.

In spite of this small disadvantage, ROEC are sometimes preferred to VIP latrines for the following reasons:

1. The pit is larger and thus has a longer life than other shallow pits;
2. Since the pits is completely displaced, the user (particularly children) have no fear of falling into it;
3. It is not possible to see the excreta in the pit; and
4. The pit can easily be empted, so that the superstructure can be a permanent facility. (3)

2.1.1.1.6 Pit Design

The volume (V) of Pits less than 4 meters deep may be calculated from the equation:

V=1.33CPN;

Where C = pit design capacity, cubic meter/person per year

P= number of people using the latrine;

N = number of years the pit is to be used before emptying.

The capacity (C) of dry pit should be 0.6 cubic meter per person per year. Where anal cleansing materials that are not readily decomposed (such as grass, leaves, maize, mud balls, cement bags, etc.) are used, this figure should be increased by 50 percent. For wet pits, the capacity should be 0.04 cubic meter per person per year.

The factor 1.33 is introduced as the pit is filled in with earth or emptied when it is three-quarters full. For the unusual case of pits deeper than 4 meters, V=CPN+1 to allow for filling the upper 1 meter with earth. Where soil condition permit, large diameter or cross-section pits may be constructed, although special care must be given to supporting the latrine base and superstructure. (3)

2.1.1.2.1 Septic Tank

Septic tanks are rectangular chambers, usually sited just below ground level, that receive both excreta and flushwater from flush toilets and all other household wastewater. The mean hydraulic retention time in the tank is usually 1 to 3 days. During this time the solids settle to the bottom of the tank where they are digested anaerobically, and a thick layer of scum is formed at the surface. Although digestion of the settled solid is reasonably effective, some sludge accumulates and the tank must be desludged at regular intervals, usually once every 1 to 5 years. The effluent from septic tanks is, from a health point of view, as dangerous as raw sewage and so is ordinarily discharged to soakaways or leaching fields if the soil is sufficiently permeable; in impermeable soils either evapotranspiration beds or upflow filters can be used, it should not be discharged to surface drains or water courses without further treatment. Although septic tanks are most commonly used to treat the sewage from individual household, they can be used as communal facility for populations up to about 300.(3)

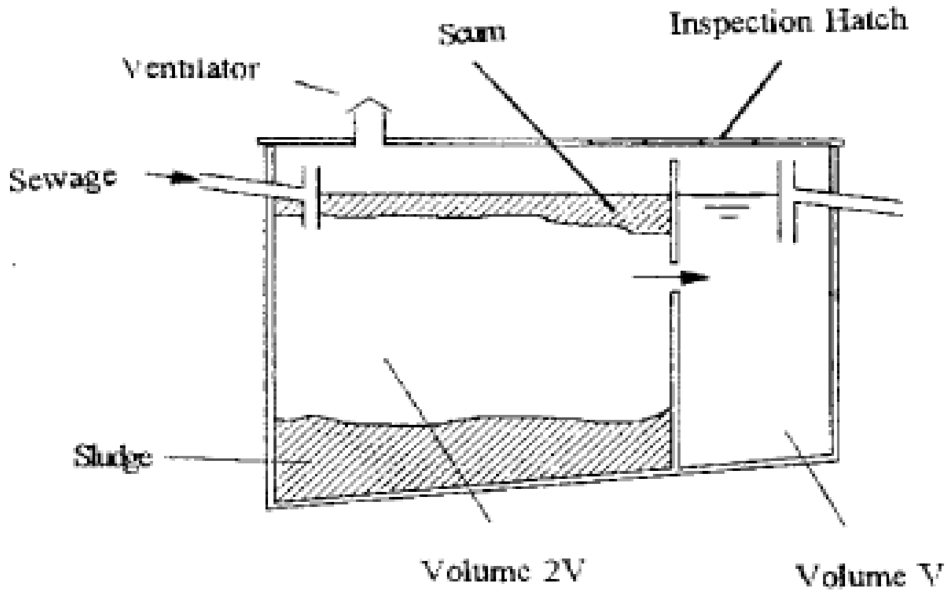


FIG. 2.3 SEPTIC TANK

2.1.1.2.2 Septic Tank Design

A two-compartment septic tank (figure 2.3) is now generally preferred to one with only a single compartment because the suspended solids concentration in its effluent is considerably lower. The first compartment is usually twice the size of the second. The liquid depth is 1 to2 meters and the overall length to breadth ratio is 2 or 3 to 1. Experience has shown that in order to provide sufficiently quiescent conditions for effective sedimentation of the sewage solids, the liquid retention time should be at least 24 hours. Two-third of the tank volume is normally reserved for the storage of accumulated sludge and scum, so that the size of the septic tank should be based on three day's retention at start-up; this ensure that there is at least 1 day retention just prior to each desludging operation. Sludge accumulates at a rate of 0.03 to 0.04 cubic meter per person yearly; thus, knowing the number of users, the interval between successive desludging operations (which are required when the tank is one-third full of sludge) is readily calculated.(3)

For smaller tank single baffle wall (two-compartment) should be provided. But for larger two baffles (three-compartment) should be provided. (1)

2.1.1.3 Aqua-Privies

The aqua privy can be regarded as a simplified septic tank system; excreta are deposited directly into a tank, rather than being flushed along a short length of pipe before reaching it. The two systems use the same principle: anaerobic fermentation or digestion of excreta in a tank of water, but an aqua privy cost less than septic tank, and requires less water for its operation.

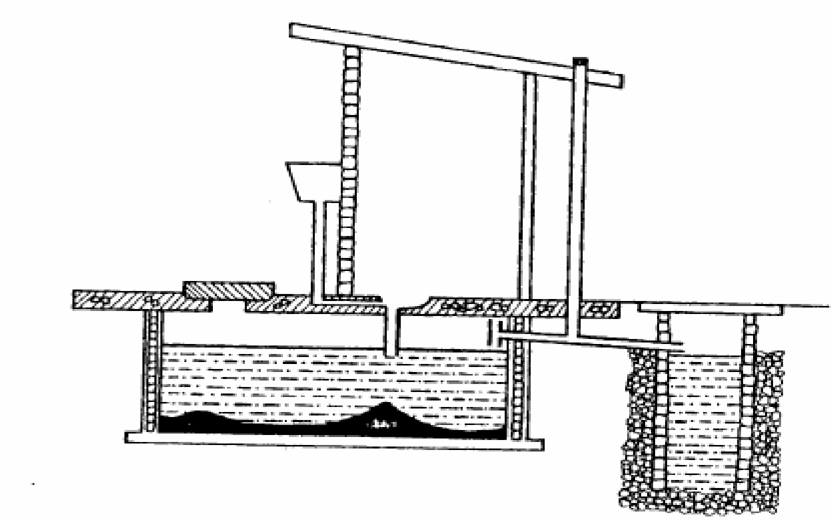


FIG. 2.4 AQUA PRIVY

The aqua privy squatting plate has an integral 100 to 150 mm diameter drop-pipe which extends some 100 mm below the liquid level in the tank, so forming a crude water seal. The tank effluent is discharged into an adjacent soakaway. It should be stressed that the liquid effluent is liable many of the pathogens originally present in the excreta. It can be highly dangerous, and soakaways must be designed with great care so that there is no danger of a surface overflow of effluent during wet weather, and danger of wells in the vicinity being polluted.(9)

2.1.2 Off-site technologies

Sewage is collected and transported to a treatment plant by a network of sewers. An out- of- date practice is to collect the human's body waste by buckets and dispose it by burning or burying, an overview of water carriage system (conventional sewerage) is provided in the next paragraph.

2.1.2.1 Conventional sewerage

The conventional cistern-flush toilet is a basically a water-seal squatting plate or pedestal unit in which excreta are deposited flushed away by 10 to 20 liters of clean, potable water that have been stored in an adjacent cistern; the cistern is connected to the household water supply and is provided with a float valve so that it automatically refills to the correct volume in readiness for the next flush. The excreta and flush water are discharged, together with all the other household wastewater (sullage), into an underground network of sewers for transport to a sewage treatment works or marine discharge station. Alternatively, in low-density areas they may be discharged into a septic tank.

Conventional sewerage is designed to transport a mixture of excreta and water from the house to the central treatment plant through a network of pipes. Usually this is done in a separate sanitary sewer system that transports only household wastewater, although some cities have combined sewer systems that carry both sewage and stormwater. Nowadays, however it is customary to build separate sewer systems rather than to provide large combined sewers, the capacity of which is only fully utilized during period of intense rain and that are likely to have dry weather flows with insufficient velocities to transport excreta.(3)

Waste water collected from municipalities and communities must ultimately be returned to receiving waters or to the land reused. The complex question facing the design engineer and public health official is: What levels of treatment must be achieved in a given application–beyond those prescribed by discharge permits to ensure protection of public health and environment? The answer to this question requires detailed analyses of local condition and needs, application of scientific knowledge and engineering judgment based on past experience, and consideration of federal, state, and local regulation. In some cases, a detailed risk assessment may be required. (6)

2.1.2.1.1 Treatment methods of Conventional sewerage

Method of treatment in which the applications of physical forces predominate is known as unit operations. Methods of treatment in which the removal of contaminants is brought about by chemical or biological reactions are known as unit processes. At the present time, unit operations and processes are grouped together to provide various levels of treatment known as preliminary, primary, advanced primary, secondary (without or with nutrient removal), and advanced (or tertiary) treatment (see table 2.1)

TABLE 2.1 LEVELS OF WASTEWATER TREATMENT (6)

Treatment level	Description
Preliminary	Removal of waste water constituents such as rags, sticks, floatable, grit and grease that may be cause maintenance or operational problems with the treatment operations, processes, and ancillary systems
Primary	Removal of a portion of the suspended solids and organic matter from the wastewater
Advanced primary	Enhanced removal of suspended solids and organic matter from the wastewater. Typically accomplished by chemical addition or filtration
Secondary	Removal of biodegradable organic matter (in solution or suspension) and suspended solids. Disinfection is also typically included in the definition of conventional secondary treatment
Secondary with nutrient removal	Removal of biodegradable organic, suspended solids, and nutrients (nitrogen, phosphorus, or both nitrogen and phosphorus
Tertiary	Removal of residual suspended solids (after secondary treatment), usually by granular medium filtration or microscreens. Disinfection is also typically a part of tertiary treatment. Nutrient removal is often included in this definition
Advanced	Removal of dissolved and suspended materials remaining after normal biological treatment when required for various water reuse applications

2.2 Quality of surface water

All surface waters should be capable of supporting aquatic life and be aesthetically pleasing. Additionally, if needed as public supply, the water must be treatable by conventional process to yield a potable water meeting the drinking-water standards. Many impoundments and rivers are also maintained at a quality suitable for swimming, water skiing, and boating. Surface waters are classified according to intended uses that dictate the specific physical, chemical, and biological quality standards, thus insuring the most beneficial uses will not be deterred by pollution. Criteria defining quality are dissolved oxygen, solids, coliform bacteria, toxic substances, pH, temperature, and other parameters as necessary.

Establishing a lower limit for dissolved oxygen protect propagation of fish and other aquatic life, as well as enhancing recreation and reducing the possibility of odors resulting from decomposition of waste organics. Cold-water fish require stringent limitation, 6 mg/l with a minimum of 7 mg/l at spawning times; and warm-water species, being more tolerant, needed a 4 to 5 mg/l limit. Dissolved solids are restricted because high concentrations interfere with agricultural, domestic, and industrial water uses. The strictest coliform standard applies to shellfish harvesting, since the meat may be eaten without being cooked. The next most stringent coliform standard is for contact recreation, where persons are likely to ingest water while swimming or water skiing. Toxic pollutants, such as heavy metals and pesticides, cause diseases, behavioral abnormalities, and physiological malfunctions in both aquatic life and humans; therefore, they must be carefully monitored and tightly controlled. The allowable pH range is 6.5 to 8.5 for protection of fishes and to control undesirable chemicals reactions. Many substances increased in toxicity in outside of this range. (2)

2.2.1 Flowing water pollution

The three classification of contamination are point sources, where wastewaters discharge from outfall sewers or drainage channels; nonpoint (diffuse) sources conveying pollutants dispersed on the land by human activities in runoff from rainfall and snowmelt; and background pollution derived from natural origins. The last varies with geology and topography of the site, kind of vegetative cover, and climatic conditions. Most frequently, runoff from uninhabited areas transports decaying organic matter, sediment, and dissolved minerals to tributary streams. (2)

To limited extend, streams and rivers have the ability to assimilate biodegradable wastes. Thus, they can recover from the effects of pollution naturally, without significant or permanent environmental damage. The capacity for self-purification depends on the strength and volume of pollutants and on the stream discharge or flow rate.

The effects of dilution and the constant flushing action of the flowing water are obvious factors involved in the waste-assimilative capacity of a stream. Not as obvious, but equally important, is the effect of oxygen transfer between the air and the water. This is called reaeration.

It is important to note that not all pollutants can be assimilated in water by natural means. This is particularly true for nonbiodegradable or persistent contaminants that do not dissipate in the environment. (7)

2.2.2 Dissolved oxygen profile

When sewage is discharge into a stream, dissolved oxygen is utilized by microorganisms as they metabolize and decompose organic substances from the wastewater. The microbes exert a biochemical oxygen demand or BOD, the BOD causes the dissolved oxygen level in the stream to gradually drop. This is illustrated in figure 2.5, as the blue curve called the stream deoxygenation curve.

While deoxygenation is occurring, oxygen from the air is dissolving into the water at the surface. The rate of oxygen transfer from the air into the water depends on temperature as well as on the oxygen deficit. The oxygen deficit is the difference between the actual DO concentration and the saturation DO value. The larger deficit, the faster of the rate oxygen transfer. This is illustrated as the red curve in figure 2.8 called stream reoxygenation curve. Notice that the slope (rate of change) of the reoxygenation gradually increased as the deoxygenation curve falls. The time is called oxygen sag curve or dissolved oxygen budget (green curve). The minimum dissolved oxygen in the stream occurs when the rate of the reoxygenation equals the rate of deoxygenation. The computation of this level is of importance in water pollution studies.

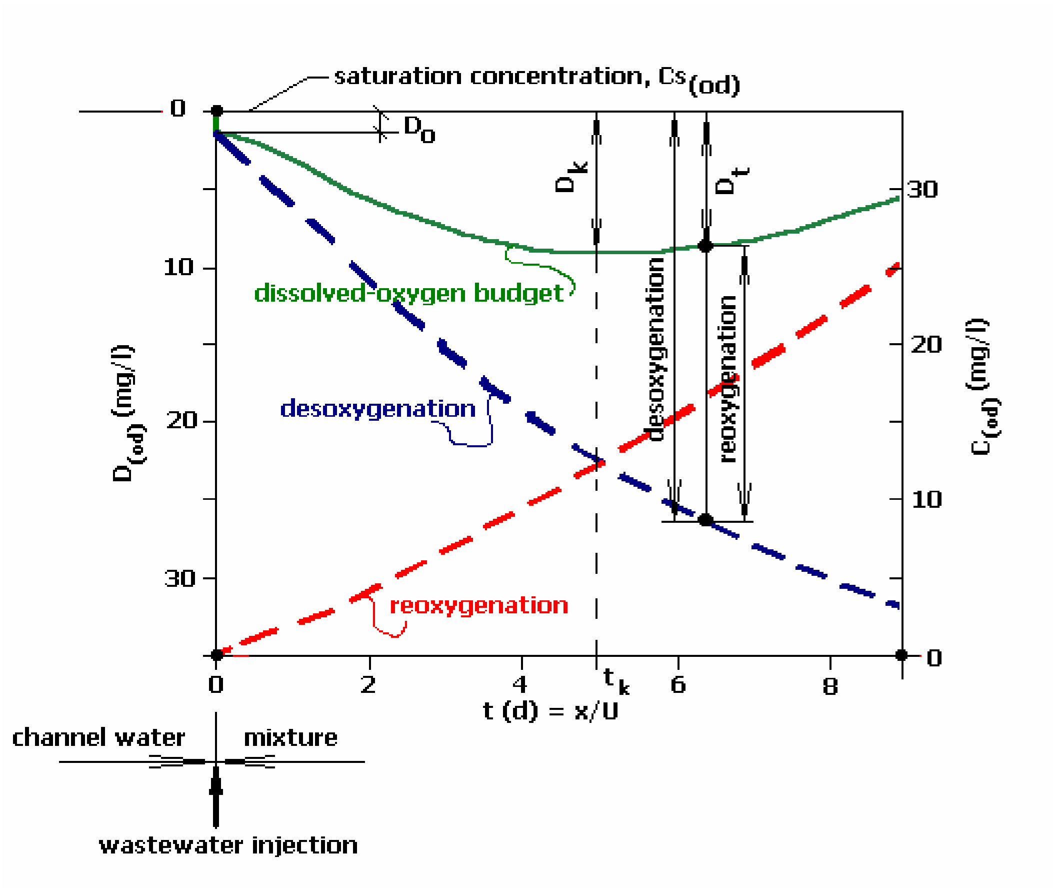


FIG. 2.5 OXYGEN SAG CURVE

2.3 Groundwater Pollution

The surface water which seeps into the ground is designated ground water. As it is travels through the surface layers of the earth, it picks up some minerals and a few organics in solution. The microorganism and particulate matter find themselves being filtered out in the upper layers. Thus it is that the most ground waters taken for below the earth's surface are free of microorganism. These waters are usually relatively low in mineral and organic contaminants. Needless to say, ground waters are usually preferred as sources of drinking water to surface water. (5)

The distance that a pollutant can travel in the ground before being separated from the groundwater depends on both the type of soil and the type of pollutant. Deposits of fine sand, for example, may remove suspended solids or bacteria from the water in a short distance, whereas coarse gravel or fissured rock could allow those pollutants to travel considerable distances. And soluble pollutants are not affected at all by the filtering action of the soil, although other processes, such as adsorption, may take place. (7)

2.3.1 Sources of Groundwater pollution

Even in areas far removed from human activity, groundwater is not pure. Although it is generally free of turbidity due to natural filtration, it is usually contain dissolved minerals. This is to be expected because the water is in intimate contact with minerals in soil and rock deposit for long period of time. Groundwater is usually harder than surface water for this reason. But, for the most part, the natural contaminants found in groundwater pose no threat to public health.

The main problems with respect to serious groundwater pollution have been improper disposal of waste and accidental spills of hazardous substances, especially from industrial activities. Petroleum products leaking from old underground storage tanks (USTs) are another source of groundwater pollution. (7)

2.4 Water and Wastewater Sampling

Proper sampling procedures are an important part of any survey to assess water or wastewater quality and to check compliance with water quality standard. A sample that has been improperly collected, preserved, transport, or identified will result in invalid and useless test result, despite the precision of the analytical lab procedure. Since the results of water quality tests are the basis for decisions that affect public health, good sampling procedures must be followed. There are two basic sampling methods: grab sampling and composite sampling. (7)

2.4.1Grab samples

As its name implies, a grab sample is a single sample collected over a very short period of time. Most people envision this as a quick "scoop," but technically it can take up to 15 min to fill the sample container and still be considered a grab sample.

It is important to note that the test results from a grab sample only represent the condition of water or wastewater at the particular time and location of sample collection. Grab sample are most suitable for chlorine residual, pH, coliforms and dissolved oxygen. They are usually collected manually.

For steam or wastewater grab sampling, devices that provide easy access to the flow channel from boats, spillways, or dock are available. Special containers that allow samples to be collected at specific depth below the surface, without mixing with air, are also available. This is particularly important for dissolved oxygen sampling. (7)

2.4.2 Composite samples

In many instance, grab samples are not enough to adequately characterize water or wastewater quality. This is particularly true for wastewater collection and treatment system in which quality as well as quantity changes from hour to hour. Composite sampling is more appropriate when it is necessary to determine overall or average conditions over a certain period of time.

Composite samples are obtained by mixing individual grab samples taken at regular intervals over the sampling period. For example, a composite sample may consist of mixture of smaller samples taken every 20 min over 8-h period.

In wastewater studies, the volumes of smaller grab samples that make up the composite are generally taken in proportion to the flow rate, for more meaningful results. For example, a composite, if a 100-ml grab sample is taken when the flow rate is 5 l/s, then a 200-ml sample would be taken when the flow increased to 10 l/s. (7)

2.4.3 General requirements

The methods for taking and preserving samples vary, depending on the specific water quality parameter and analysis to be made. A summary of four general considerations that apply for any type of sample follows:

1. The sample must be truly representative of the existing conditions. For instance, collecting a water sample from a faucet without first letting the water run for

a while, will not give results representative of condition in the water main, but only of the water that was stagnant in the service line for an unknown period of time.

2. The time between collection and analysis should be a short as possible for the most reliable results. Certain tests, such as chlorine residual or temperature tests must be determined immediately. Dissolved oxygen (DO) is another parameter that needs immediate analysis, although it is possible to add a chemical that fixes the DO concentration, allowing later testing in the lab.

3. Appropriate preservation techniques should be applied to slow down the biological or chemical change that may occur between in the time between sample collection and sample analysis. This usually involves refrigeration to cool the sample or chemical fixing (as for DO).

4. Accurate and through sampling records. Must be kept to avoid any confusion as to the "what, when, and where" of the sample, as well as to satisfy legal requirements. (7)

CHAPTER THREE

MATERIALS & METHODS

CHAPTER THREE

MATERIALS & METHODS

3.1 General View to Khartoum State

Khartoum state locates in 22,000 square kilometers, between longitudes 31.5 – 34.45 degree east, and latitudes 15.8 – 16.45 degree north. The climate is semi desert, the mean of maximum temperature is 41.1^{o}C and mean of minimum temperature is 22.7^{o}C. The average of rainfall rates about 150 mm. (17)

Figure 3.1 Khartoum state (study area) *

For nearly two centuries people from different ethnic groups have gravitated to Khartoum, like the rivers, collided, and blended. Greater Khartoum actually encompasses three different cities. Khartoum served as the colonial administrative center during Ottoman and Anglo-Egyptian rule and is now the seat of government. Omdurman, a more traditional Sudanese town, has mudbrick houses and inner

* http://www.khartoumstate.gov.sd/

courtyards. The third urban region, Khartoum North, is the newest settlement. There, industrial development has taken place.

In the capital, modern industry mingles with traditional settlement. Edible oils factories stand with small factories churning out everything from dried fruits to footwear, textiles, and cosmetics. Steel silos and wheat processing plants tower over small family-run bakeries.

Perhaps as many as seven or eight million people, including some million displaced by the war, currently live in the greater Khartoum region; Most have come in search of employment opportunities. (15)

Multiple indicator cluster survey (2000)† which was carried out by federal ministry of health, UNICEF, and central bureau of statistic figures that 85.5% of Khartoum state population is urban and 12.5% is rural, Infant Mortality rate is 70, less than 5 years old mortality rate is 100, Percentage of children of primary school age attending primary school is 69%, More than two thirds of children who enter the first grade of primary school eventually reach grade five, 67% of households (HH) are rich, 15% are poor and 18% are intermediate.

3.2 Municipality Engineering History in Khartoum State (12, 13, 16)

3.2.1 First plans

The municipality engineering was brought to Sudan since the beginning of the previous century, when the towns started to be progressed and developed. The first plan of towns division was implemented in Khartoum 1902 by the order of the general British governor "Kitchener", this plan fulfilled the following:

Chord streets were designed for military causes in order to control over the town through these chord streets.

The streets were obviously wide (30-40 meter).

There was concentration on country's capital because of it is political, economic, commercial, cultural and social importance, furthermore the capital includes the most important commercial activities, governmental institutions, educational institutions, and the private commercial companies, and it represents the center of the government in which there are the foreign embassies, great hotels, and headquarters of the banks. The capital in it is three towns: Khartoum, Khartoum north, and Omdurman represent the main axis of transports and the international, regional, and local communication.

† http://www.childinfo.org/MICS2/newreports/sudan1/FianalMICSSudan.pdf

Once this plan was put in implementation, the municipality engineering took it is leading and pioneering position in the development of the country.

The major "Stanton" described the beginning of new Khartoum's development according to the plan mentioned above, as "the land of the old Khartoum was leveled with the help of some military parties, streets were constructed through the debris and rubbles, then the important works were done after having necessary financing and many general services were served. It seemed difficult to have enough land that was owned by Sudanese people who loved owning lands. A compromise was made to solve the problems, and then the buildings were constructed. The year 1909 witnessed the birth of the first revolution of the municipality projects which represented in establishing Khartoum water station, which consisted of: a complete unit of water filtration, pure water reservoir, and the unit of water pumping from the reservoir to the pressure basin, to distribute the drinking water to the Europeans buildings, hotels, commercial places of high prestige and some Sudanese houses."

Then the railway and the construction of the Blue Nile Bridge have participated in the town's progress.

The municipality engineering Dr. W. A. Macleans presented a new general plan in 1912 which help in extending Khartoum town toward south and west inside the boundaries designed through the railway. Khartoum town continued progressing in a very harmonies way within the projects of planning prepared under supervision of the municipality engineer, and the manager of survey department.

Due to the lack of financing it was not good to establish an independent department for the municipality engineering, so it was affiliating to responsibilities of the engineering section headmaster in old Gordon College. The headmaster was responsible of the implementation of the municipality engineering works in the three towns. The project preparation in the engineering school was done by the students within the headmaster and board's help, then would be endorsed by the town council which a pointed by the governor who is the head of that council in same time. The projects were to be implemented by contractors or directly by the worker's organizations under supervision and direction of teaching board and engineering section students. Whereas the responsibilities of the municipality engineering were simple and confined to the streets construction (of about one kilometer yearly), rain water drainage, construction and repairing of the old buildings of the municipality. The first section of municipality engineering was brought to Sudan by the year 1936 in Khartoum town, an engineer of municipality was a pointed for assistant member, those were to be responsible of the municipality engineering in Khartoum, Khartoum north and Omdurman a number of members were being sent to have suitable training to solve the simple problems that were face them. In 1956 the municipality engineer was appointed as a technical, with considerable responsibilities, to meet the fundamental needs of the population in constructing and repairing streets, rain water drainage, school buildings, healthy units, public markets, and housing projects, and all these works were done within the public financing collected from the taxes and imposts, for the interest of the town and its population. The responsible units in Sudan became about 90, 18 of them were municipal council, 72 of them were rural council. And the most of these units were including engineering departments meanwhile there was a few number of councils which had efficient engineering departments, and consist of a respectful number of engineers who were few in the country within the hard financial situation, and the absence of the qualified engineer to manage the units of performance in the concerned ministries. It was clear that the works of the municipality engineering were more progressed in Khartoum and Portsudan than in the rest of the country, because of accumulation of the competent engineers in the capital, and also the successive governments made the development of the capital as their top priority.

The sewers project of Khartoum and Khartoum north was joined to the administration of sanitary engineering which aimed to promote the standard of the environmental health, treating the impure water, reforming projects, promoting wastewater disposal systems services and designing its units, studying developments projects implementing the local orders of the wastewater disposal systems and combating pollution.

3.2.2 Rainwater drainage system

A good system of rainwater drainage was established to be cared of it. It was noted that the rain falls during two or three months a year, but it was much intensified. It is enough to say: the rainfall including a lot of healthy, social and psychological crisis, but many of cities were facing economic problems accompanying the lack of finance of sanitation projects, even in the national capital, whereas a lot of money was paid to finance the current drainage systems which represent the contemporary drainage systems considered as one of the characteristics of the streets in many cities.

The rainwater drainage system used in whole the country consists of public surface drainage and small open canals for the sub drainages. The majority of these drainages were designed to drain all the rainwater from the three towns within 72 hours, the falling rain water is estimated randomly to the rate of a hypothetic fixed falling which is estimated as one inch through every area. The size of the drainage is to be determined in 72 hours, and then divided into the velocity of flow which was estimated, two feet per a second. This random way of designing was forgotten by the coming of the modern scientific research and the progress of the water flow estimation.

The method of time concentration was adopted in designing rainwater drainage in the last years in order to estimate the intensity and the time of the rain by rainfall intensity curve confined to Khartoum town.

The curve was prepared since 1955 by collecting the records of storms from 1950 to 1955 by using the rain automatic measure devices placed in Khartoum airport, center of Khartoum and Shambat, then the size of drainage will be determined by manning equation. The curve was designed for analyses the storm and its intensity (in total 150 storms). The development of the curve in 1960 was based on the records of rain during ten years, and the curve represents the intensity of repetition for two year. One the best drainages that participated in Khartoum development is the drainage M-N which its foundation finished march 1956, it was establish to serve the populated area in the south of new Deum which still till 1955 exposed to continued sweeping away during the rainy seasons. The last one of its disaster was in 1954 which destructed about 400 housing units completely. Once the drainage was built all area around is protected.

3.2.3 Wastewater disposal systems

One of the oldest ways used is the night soil (bucket system). In this system a bucket will be but in any toilette to keep the waste then it will be taken to outskirts to get rid of it. But this system was rejected because of it is high cost; it is bad health impact and the lack of manpower to perform the work.

Another system were used such as cesspool and water privy in a lot of towns. Once the rural areas started to use the pit system it was replaced in the towns by using the anaerobic digester system (septic tank) and wells which can go aside with the new sanitary modern elements, but for it's high cost it did not spread in the countryside.

On the other hand, the commercial waste which faced a lot of impediments especially in the industrial towns like Khartoum North, and the current system is not good due to the health problems that are resulted from the open surface sewers that disposed the waste to the east of the town.

However, all these mentioned systems do not solve the problems of drainage liquid and excremental wastes. Other factors also play a big deal in the problems as: the quick progress of urban areas and the migration towards them, industrial prosperity and rising up of living standard

Khartoum town municipality knew that it is very important to rethink about using new good system to take away the liquid and commercial wastes especially in the industrial areas, so the Khartoum sewer network was built in 1954 to receive the excremental wastes from all the populated area which from the north, Blue Nile, and 71 street, from the south. Except new Diom. The population served by this sewer network were represented as 80,000 for the estimation of total flow 3.2 million gallons (14546 cubic meter) and a complete treating of a peak flow Qp = 3Qav.

The project was executed from 1953 to 1954 and the Goaze station was inaugurated officially in 17th November 1959, this project provides the city by 14 sub drainage and 12 lift and pump station. The station number 6 was near the Mussalmia Bridge was the main station following by the station number 9 situated in Hurria Street, these two stations pump to the Goaze drainages, in addition to that, they serve the other stations. After the rebuilding was achieved by some Japanese the number of the stations reaches 16. the assisting drainages collect the waste of the buildings and let them go to a general drainage which drains it under the gravity to the rooms of the pumping station collection, then it will be raised by using the electric energy to the high sewer which can drain it out to the two main holes nearly the bridge of almussalmia and the industrial area, then it will be raised later through raising pipes to the drainage stations which it's wideness is about 3.2 million gallons a day.

The retreating stations include: screens sedimentation tanks, sludge digester, dry beds, trickling filters, and three grit removal chambers (two of them work at the same time). This station contains four sedimentation tanks the diameter of each one is 14 meters, and each one has deepness about 2.5 meters, in each tank there is an automatic sludge cleaner with rotation speed 7.5 feet per minute. Tanks were designed to for 3 hours retention time at average flow, and one hour at peak flow. Biological treatment was achieved by 16 circular trickling filters with 32 meters diameter for each one, the total filtration layer (stones) was 23000 cubic meters. There were also four circular humus tanks which have the same deepness and diameter of sedimentation tanks. The two sludge digester tanks diameter was 20 meters with side deepness 5.7 meters and central deepness 11 meters. The total area of dry beds and grit removal equals 19200 square meters. Then the treated water will be pumped by lifting pipes with 45 kilometer length and 0.8 meter diameter, to irrigate the green belt and Algaba (forest) region located in south of Khartoum. The project was implemented by "Marbles red joy" British company, whereas the designing and survey work was done by the British company "hoardy hungry". This project cost was 2.2 million pounds .The network length equals 168 kilometers and began to work in 1959, its geographical boundaries: Nile street in the north, Amarat 61 street in the south, the international Khartoum fair in the east, and Hilton hotel nearby the joint point of the two Niles in the west. Then the Amarat quarter was added to it in 1962, as a result of the population increasing, and the vertical and horizontal building extensions, the discharge reached three times the design capacity, this yielded the reducing of performance, unsuitable effluent water from the treatment plant, more seepage from network, and deterioration in environment around the treatment plant, then the Goaze treatment plant was canceled, and was replaced by lifting station to pump the flow to green belt which was designed to receive 22 million gallons per day. In 1985 the station of Soba was founded to reduce the hydraulic and biological loads. Some stations were rehabilitated in 1986 by British company "sigmond", and other stations were built in 1990 by Japanese "konoiky" company, soba station also was rehabilitated to receive average discharge capacity 31420 cubic meters per day (12620 domestic waste, 14300 commercial waste, 4500 industrial waste) this station is working by stabilization ponds system (4 anaerobic ponds, 2 facultative ponds, and 2 maturation ponds), adding to that the establishment of a new pumping station inside which there are administrative buildings and a laboratory.

In which concern the Khartoum north sanitary sewers project, it completed the first phase of the industrial area in 1971 with a capacity of six million gallons per a day, it has two lift stations and one station of pump increasing. The treatment plant was located in Alhajyousif, in which there are screens, grit chamber, sedimentation tank, 4 sludge digesters, 16 dry beds, 10 stabilization pond among which 4 are anaerobic, 4 aerobic, and the last two are maturation ponds. But this plant didn't work well for many reasons and now there is continuous working to rehabilitate it with activated sludge process.

3.3 Scope of the Study

This dissertation was carried out in Khartoum state covered all its seven localities (urban and rural areas) the work concerned this study was included:

* Surface water samples (collection and analyses)

* Septic tanks effluent samples (collection and analysis)

* 500 random Questionnaire (filling and analyses)

All samples were analyzed in sanitary laboratory of the University of Khartoum (civil engineering department). The data collected by the survey was processed by the help of the computer programs (SPSS & Excel)

3.4 Locations of Surface Water Samples

Samples of surface water examination were taken from selected locations of River Nile, Blue Nile, and White Nile as shown in Figure (3.1).

3.4.1 River Nile sampling

Locations selected from river Nile were (from upstream to downstream):

- Near the national assembly (just downstream Almoqran); this location was selected to be compared with the points of White Nile and Blue Nile just upstream almoqran. (R1)
- Almorada, near the fish market; in this location the fishes are cleaned and the wastes are directly flown in the stream. (R2)
- Near the national television and Broadcast Corporation. (R3)
- Alsarha (Nile town); in this location there are many red-brick kilns which use animals wastes. (R4)

3.4.2 Blue Nile sampling

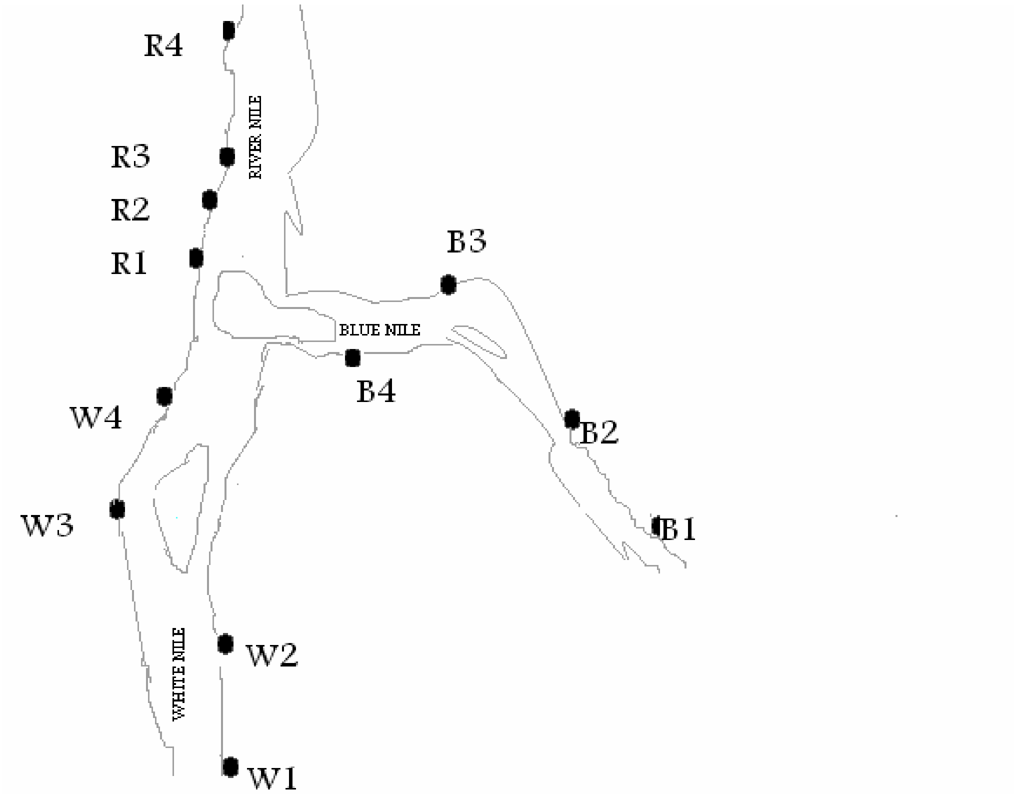
Locations selected from Blue Nile were (from upstream to downstream):

- Aljareef, near Almansheea Bridge; in this location there are many red-brick kilns which use animals wastes. (B1)
- Hillat kuku, near the effluent of Mahmud shareef electricity station. (B2)
- Near friendship palace hotel; this location is defendant that it receives septic tank effluent from nearby hotel. (B3)
- Near almogran family park. (B4)

3.4.3 White Nile sampling

Locations selected from White Nile were (from upstream to downstream):

- Alkalakla alquba, near alquba; this location was selected to be compared with other defendants points in this river. (W1)
- Alshajra, near the army depositaries. (W2)
- Alfitahab, about 1.5 kilometer south of Elingaz bridge; in this location the river is used for trucks cleaning and washing, receives the wastewater and some oil from the trucks. (W3)
- Near the White Nile Bridge; this location is defendant that it receives wastewater effluent from nearby sewer network. (W4)



River Nile		Blue Nile		White Nile	
R1	National assembly	B1	Aljreeef (east)	W1	Alkalkla algoba
R2	Almurada	B2	Hilat kuku	W2	Alshajra
R3	TV corp.	B3	Friendship palace	W3	Alfithab
R4	Nile town	B4	Almogran	W4	Medical arm

Figure 3.2 Locations of surface water samples

3.5 Methods of Analysis of Surface Water Samples

3.5.1 Physical analyses

3.5.1.1 Turbidity

Insoluble particles of soil, organics, microorganisms, and other materials impede the passage of light through water by scattering and absorbing the rays. This interference of light passage through water is referred to as turbidity. Measurement of turbidity in treated drinking water, commonly less than one unit, is measured using a precalibrated commercial turbidimeter (nephelometer). Units of turbidity using a nephelometer are expressed as Nephelometric Turbidity Units (NTU). (2)

The turbiditimeter was used in this research shown in Figure (3.2)

3.5.2 Chemical analysis

3.5.2.1 Dissolved oxygen

Dissolved oxygen (DO) is generally considered to be one of the most important parameters of water quality in streams, rivers, and lakes. Just as people need oxygen in the air they breathe, fish and other aquatic organism need DO in the water to survive. With most other substances, the less there is in the water, the better is the quality. But the situation is reversed for DO. The higher the concentration of dissolved oxygen, the better is the water quality. The azide modification of the iodometric is the most common chemical technique for measuring dissolved oxygen. This method was used to determine DO in all our samples.

3.5.2.2 Biochemical oxygen demand

The traditional BOD test is conducted in standard 300-ml glass BOD bottles. The test for the 5-d BOD of a water sample involves taking two DO measurements: an initial measurement when the test begins, at time t = 0, and a second measurement, at t = 5, after the sample has been incubated in the dark for 5 d at 20oC. The BOD5 is simply the difference between the two measurements; this traditional method was used for some samples when the modern digital BOD track had fallen. Figure 3.3 shows BOD digital apparatus.

3.5.2.3 Chemical oxygen demand

Chemical oxygen demand (COD) is widely used to characterize the organic strength of wastewaters and pollution of natural waters. The test measures the amount of oxygen required for chemical oxidation of organic matter in the sample to carbon dioxide and water. The apparatus used in the dichromate reflux method pictured in figure 3.4 consist of an Erlenmeyer flask fitted with a condenser and a hot plate.

3.5.2.4 Nitrogen

Nitrogen, N_2, occurs in many forms in the environment and takes part in many biochemical reactions. The four forms of nitrogen that are of particular significance in environmental technology are organic nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen. In water contaminated with sewage, most of the nitrogen is originally present in the form of complex organic molecules (proteins) and ammonia, NH_3. These substances are eventually broken down by microbes to form nitrite and nitrate.

Ammonia of surface water samples was measured by direct reading using ion specific meter as shown in figure 3.5 or by titration method. Nitrate was measured using nitrate reagent which had been added to 10 ml of sample and noting the change in color as shown in figure 3.6

Figure 3.3 Turbiditimeter (HACH Company 4600-00)

Figure 3.4 Biochemical Oxygen Demand (BOD) digital tracks (HACH Company)

Figure 3.5 Chemical Oxygen Demand (COD) apparatus

Figure 3.6 Ammonia measurement apparatus
(HANNA instruments)

Figure 3.7 Nitrate test

3.5.2.5 Oil and grease

A variety of organic substances including hydrocarbons, fats, oils, waxes, and high-molecular-weight fatty acids are collectively referred to as oil and grease. Their importance in municipal and industrial wastes is related to their difficulty in handling and treatment. The Extraction method has been used to determine oil and grease values.

3.5.2.6 pH

The pH is a measure of the intensity of the acidity or alkalinity, the primary reason for measuring the acidity, alkalinity, and pH of water is to be able to control the water treatment process in a water purification facility. The required doses of various chemicals depend on the concentration of acidity or alkalinity, or on the pH of the water. To determine the pH of the samples, direct reading by pH meter used as shown in figure 3.7

3.5.2.7 Total dissolved solid (TDS)

Solids occur in water either in solution or in suspension. In drinking water, dissolved solids may cause taste problems, hardness, corrosion, or esthetic problems may also accompany excessive TDS concentration. As shown in figure 3.8, direct reading for TDS values was used.

Figure 3.8 pH meter (HANNA instruments)

Figure 3.9 TDS meter (HANNA instruments)

3.5.3 Biological tests

The standard method for enumerating bacteria is the pour-plate counting method. In this method 1 ml of the diluted sample containing between 30 and 300 organisms per milliliter is added to a sterile Petri dish. Approximately 10 to 15 ml of sterile media such as tryptone glucose agar in a molten state at 45oC is poured over in the sample in the Petri dish. The sample and the agar are thoroughly mixed and the agar allowed solidifying. The plates are incubated 24 to 48 hr and then the number of colonies is counted. (5)

The media has been used to total coliform "Total Endo Agar Base", and "EMB" agar has been used as media to fecal coliform. Figure 3.9 shows Petri dish after incubation.

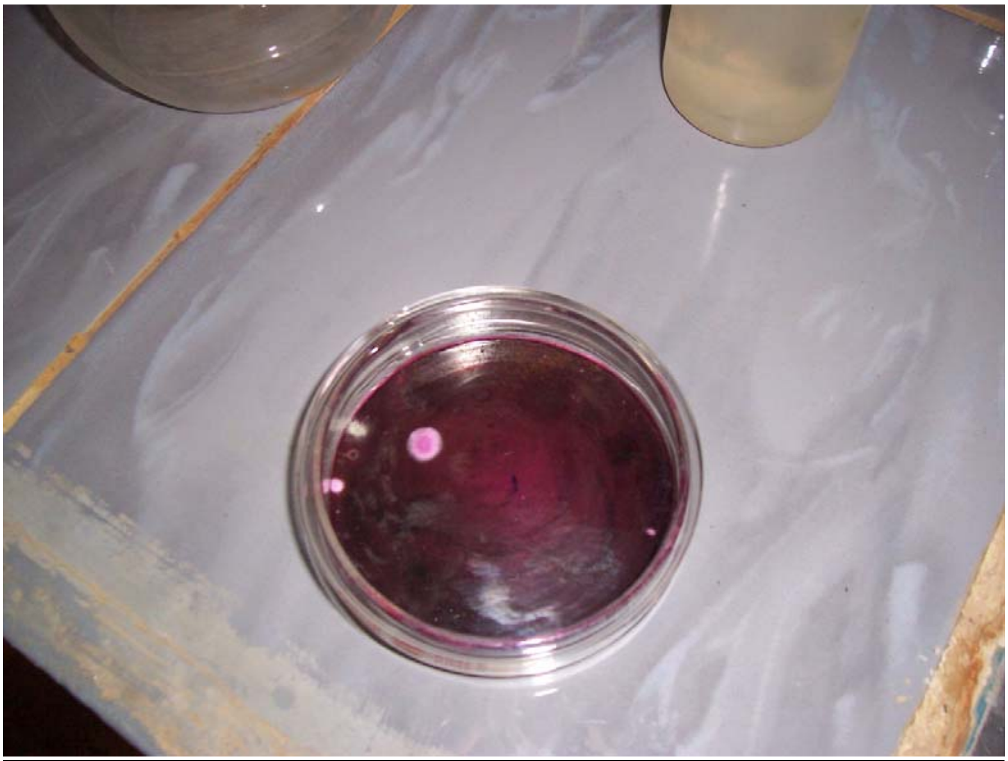


Figure 3.10 Pour-plate fecal coliform bacteria colonies

3.6 Sampling from Soakaway Wells

Septic tank effluent samples have been taken from nine locations in Khartoum state, each three of them from town (Khartoum, Khartoum north, and Omdurman). Any sample has been taken from the disposal well which receives the septic tank effluent as shown in figure 3.10. The locations selected for sampling were tabulated below:

Khartoum town		**Kh. North town**		**Omdurman town**	
K1	Burri	N1	Shambat	O1	Almurada
K2	Almujhdeen	N2	Aldrushab	O2	almuhandseen
K3	Alkalakla	N3	Al alafun	O3	Umbada

Table 3.1 Locations of septic tank effluent sampling

Figure 3.11 Soakaway well receives septic tank effluent.

3.7 Method of Analyses of Soakaway Wells Samples

Tests have been done for septic tank effluent samples include:

- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Ammonia nitrogen
- Nitrate nitrogen

All these tests have been done as in analyses of surface water which was explained in section 3.2

3.8 Questionnaire Design and Fieldwork

The questionnaire sheet which designed for collection of data required for this study contains eighteen questions. These questions covering the following variables:

a- Family characteristics.

b- Sanitation system used in the house and it is problems.

c- Frequency of diseases.

d- Resource of water.

e- Quality of water.

f- Consumption of water.

g- Cost of water.

h- Solid waste disposal method.

"See appendix"

Estimated population of Khartoum state according to web site of government of Khartoum state is 6,925,980.(14) Quota Sampling technique have been used to divide 500 random questionnaire, depending on percentage population of each locality of the state, as shown in following table:

Table 3.2 Localities population and questionnaire distribution

locality	Population	Percentage (%)	Questionnaire frequency
Khartoum	745,938	10,7	54
Jebel awlia	1,703,950	24,6	123
Kh. north	533,700	7,8	38
East of Nile	1,184,000	17,0	85
Omdurman	508,401	7,4	37
Kerary	750,000	10,8	54
Umbada	1,500,000	21,7	109
TOTAL	**6,952,989**	**100%**	**500**

The distribution and collection of the questionnaires took about four months, starting in august 2006. Within this period 500 questionnaires were distributed and collected.

Seventy percent of the questionnaires were distributed by me, while the rest were done by some people under my direct supervision.

After the collection of questionnaires, the processing of the data was started. This includes editing, coding, tabulation, and statistical analyses using "SPSS 10" computer program, but some graphs were done using Microsoft Office Excel.

CHAPTER FOUR

RESULTS, DATA ANALYSIS AND DISCUSSION

CHAPTER FOUR

RESULTS, DATA ANALYSIS AND DISCUSSION

4.1 Results of Surface Water Quality

As mentioned in chapter three, samples are selected from river Nile, White Nile, and Blue Nile. Locations were encoded as shown in the following table:

Table 4.1 Surface water samples locations

River Nile		**Blue Nile**		**White Nile**	
R1	National assembly	B1	Aljreeef (east)	W1	Alkalkla algoba
R2	Almurada	B2	Hilat kuku	W2	Alshajra
R3	TV corp.	B3	Friendship palace	W3	Alfithab
R4	Nile town	B4	Almogran	W4	Medical arm

4.1.1 Physical Tests

4.1.1.1 Turbidity

Table 4.2 Turbidity of surface water samples

Location	June Samples Turbidity (NTU)	January Samples Turbidity (NTU)
B1	1332	15.8
B2	556	26.5
B3	1000	12.4
B4	979	84.9
W1	848	36.6
W2	249	28.6
W3	546	236
W4	503	97.2
R1	299	134
R2	465	202
R3	318	158
R4	314	82.2

4.1.2 Chemical Tests

4.1.2.1 Dissolved Oxygen

Table 4.3 Dissolved Oxygen's of surface water samples

Location	Dissolved oxygen of June Samples (mg/l)	Dissolved oxygen of January Samples (mg/l)
B1	5.85	6.7
B2	6.95	6.5
B3	6.35	7.75
B4	6.55	6.85
W1	6.75	6.7
W2	6.95	9
W3	7	8.2
W4	7.15	7
R1	4.15	8.55
R2	1.65	8
R3	5.9	7.4

R4	6.05	8.35

4.1.2.2 Biochemical Oxygen Demand

Table 4.4 Biochemical Oxygen Demand (BOD) of surface water samples

Location	BOD of June samples (mg/l)	BOD of January samples (mg/l)
B1	6	2.65
B2	Nil	1.6
B3	6	0.9
B4	55	14.558
W1	Nil	0.6
W2	251	249.5
W3	7.3	2.31
W4	No sample	209.95
R1	0.083	10.04
R2	1.167	55.2
R3	5.33	5.42
R4	3.92	3.12

4.1.2.3 Chemical Oxygen Demand

Table 4.5 Chemical Oxygen Demand of surface water samples

Location	COD of June Samples (mg/l)	COD of January Samples (mg/l)
B1	200	33
B2	150	200
B3	100	81
B4	190	210
W1	90	71
W2	270	400
W3	10	85
W4	945	350
R1	30	30
R2	165	345
R3	120	145
R4	105	190

4.1.2.4 Nitrogen

Table 4.6 Ammonia of surface water samples

Location	Ammonia of June samples (mg/l)	Nitrate of June samples	Ammonia of January samples (mg/l)	Nitrate of January samples
B1	2.5	nil	0.048	nil
B2	2.5	nil	0.122	nil
B3	2.25	nil	Nil	nil
B4	2	nil	0.146	nil
W1	1.26	nil	0.061	nil
W2	3	nil	0.097	nil
W3	1	trace	0.316	nil

W4	1.25	trace	Nil	nil
R1	0.75	trace	0.45	nil
R2	2	nil	0.523	nil
R3	1	nil	0.559	nil
R4	1.75	nil	0.705	nil

4.1.2.5 Oil and grease

Table 4.7 Oil & grease of surface water samples

Location	Oil &grease of June samples (mg/l)	Oil & grease of January samples (mg/l)
B1	50.1	38.2
B2	12.1	12. 9
B3	30.25	14.9
B4	7.65	24.3
W1	3.1	16.39
W2	2.8	21.8
W3	1	47.9
W4	3.6	6.5
R1	2.45	30.9
R2	14.5	9.5
R3	35.5	36.1
R4	3	10.8

4.1.2.6 pH

Table 4.8 pH of surface water samples

Location	pH of June samples	pH of January samples
B1	8.7	8.4
B2	8.4	8.5
B3	8.2	8.9
B4	8.4	8.5
W1	7.9	8.6
W2	8.7	9.2
W3	8.9	9.1
W4	9	8.5
R1	8.7	8.5
R2	8.8	8.4
R3	8.4	8.4
R4	8.6	9

4.1.2.7 Total Dissolved Solid

Table 4.9 Total Dissolved Solid of surface water samples

Location	TDS of June samples (micros/cm)	TDS of January samples (micros/cm)
B1	60	60
B2	110	75
B3	60	60

B4	60	70
W1	75	50
W2	70	50
W3	90	60
W4	70	65
R1	80	60
R2	90	70
R3	<10	60
R4	80	60

4.1.3 Biological Tests

Table 4.10 Fecal & total coliform of surface water samples

Location	Fecal coliform of June samples	Fecal coliform of January samples	Total coliform of June samples (cfu[‡]/100ml)	Total coliform of January samples (cfu/100ml)
B1	3500	5,000	61,500	56,500
B2	1000	1,000	15,000	44,500
B3	2500	Nil	90,000	440,000
B4	1500	5	50,000	45
W1	30000	1,500	70,000	530,000
W2	7500	2,500	115,000	45,000
W3	Nil	15	10,000	425
W4	Nil	3,500	2,000	39,000
R1	Nil	10	20,000	75
R2	500	225	150,000	1,200
R3	31000	10	51,000	130
R4	5000	10	160,000	155

4.2 Results of Soakaway Wells Water Quality

Table 4.11 Result of tests of soakaway wells water samples

Sample No.	**Location**			**BOD mg/l**	**COD mg/l**	**Ammonia mg/l**	**Nitrates mg/l**
1	Khartoum	Burri	K1	309.27	350	23.15264	5.0
2		Almujhdeen	K2	283.92	365	21.10976	Nil
3		Alkalakla	K3	390.39	940	39.49568	Trace
4		Shambat	N1	268.71	290	19.74784	Trace

[‡] cfu = colony-forming unit

5	Khartoum	Aldrushab	N2	349.83	360	39.49568	-
6	north	Al alafun	N3	202.8	290	32.68608	Trace
7		Almurada	O1	91.26	105	8.85248	Trace
8	Omdurman	almuhandseen	O2	299.13	320	25.87648	Nil
9		Umbada	O3	-	150	32.68608	-

4.3 Results of Questionnaire

4.3.1 Mean of Members of Family

Table 4.12 Localities populations and mean of number of family members

locality	Population	Percentage	Questionnaire frequency	Mean of family No.
Khartoum	745,938	10,7	54	7.89
Jebel awlia	1,703,950	24,6	123	7.48
Kh. north	533,700	7,8	38	7.1
East of Nile	1,184,000	17,0	85	8.2
Omdurman	508,401	7,4	37	8.31
Kerary	750,000	10,8	54	7.87
Umbada	1,500,000	21,7	109	8.07
TOTAL	6,952,989	100	500	7.9

4.3.2 Types of Sanitation Systems Used

Table 4.13 Frequency & percentage of sanitation systems

Sanitation system	Frequency	Percentage %
Pit latrine	367	73.4
Sep& well	107	21.4
Sewer Network	7	1.4
others	19	3.8
TOTAL	500	100

Table 4.14 Types of pit latrine used

Pit type	Frequency	Percentage %
VIP	139	37.6
Conventional pit	231	62.4

Table 4.15 Pit latrine dug until water table

	Frequency	Percentage %
Pit reach g. water	43	11.7
Not reach water	324	88.3

4.3.3 Problems Faced Sanitation Systems Users

Table 4.16 Problems due to pit latrine

Problem	Percentage (%)
Flies	44
Mosq. & insects	50,9
Odor	73,3
No problem	27,5

Table 4.17 Pit types and problems percentage

Pit type	Flies (%)	Mosq. & insects (%)	Odor (%)	No problem (%)
Ventilated	37,4	46,7	28	34,5
Conventional	47,1	54,11	43,3	23,8

Table 4.18 Pit depths and problems percentage

Depth of content	Flies (%)	Insects & mosquitoes (%)	Odor (%)	No problem (%)
Nearly full	60	68.3	73.3	11.3
Middle depth	49	47.1	39.6	22.6
Low depth	39.3	47.7	28.6	32
Total	44	50.9	37.3	27.4

Table 4.19 Problems of sewer & septic systems

Problem	Sewer network (%)	Sep. & well (%)	Sep. & tanker (%)	Sep. & soakaway (%)
Overflow	42.8	25.2	25	0
Cleaning frequency	0	11.2	50	0
No problem	57.2	64	50	100

Table 4.20 Interesting in sewer network

Are you interest in sewer network?	Percentage (%)
Yes	60
No	10.2
I don't know	29.8

Table 4.21 Reasons of rejecting sewer network

Why are you rejecting sewer network?	Percentage (%)
I don't need it	34
The bad side effect of current network	39.6
Economical reason	26.4

4.3.4 Diseases Frequency

Table 4.22 Diseases frequency

Diseases	frequency	Percentage%
diarrhea	76	15.2
malaria	194	38.8

dysentery	69	13.8
inflammations	74	14.8
Guardia	12	2.4
No diseases	223	44.6

4.3.5 Water Quality, Consumption and Cost

Table 4.23 Water quality

Water Quality	Frequency	Percentage%
Good	289	57.8
Hi. turbidity	41	8.2
Odor	12	2.4
Salt	138	27.6
Bad taste	35	7
Color	1	0.2
Sediment	3	0.6

Table 4.24 Water qualities and diseases frequency

Water quality	Diarrhea (%)	Dysentery (%)	Malaria (%)	Inflammations (%)	Guardia (%)	No disease (%)	Total (%)
Good	14.5	12.8	36	15.9	1	47.4	57.8
Salt	18	15.8	43.8	11.5	3.6	40.28	27.6
Taste	17.1	14.2	37.1	2.9	0	43	0.07
Turbidity	12.2	12.2	34.1	17.1	4.9	43.9	0.082
Odor	30.8	15.4	30.8	15.4	0	38.4	0.024
Sediment	0	0	33.3	0	33.3	33.3	0.006
Color	0	0	0	0	0	100	0.002

Table 4.25 Water consumption of each locality

Locality	Mean water consumption
Jabel awlea	39.9
Khartoum	66.81
Bahri	58.05
Sh. Alneel	43.95
Omdurman	55.96
Karay	50.3
Umpeda	43.5
Total	48.13

Table 4.26 The consumers' opinion in water cost

Water cost	Percentage
Cheap	3.6
Expensive	57.8
Suitable	38.6

4.3.6 Solid Waste Disposal Systems

Table 4.27 Solid waste disposal systems

Solid waste disposal system	Frequency	Percentage (%)
Municipality car	388	77.6
cab carriage (karro)	5	1.0
Outdoors (kosha)	52	10.4
In the open	13	2.6
burned	30	6.0
station	12	2.4
Total	500	100.0

4.4 Analysis and Discussion of Surface Water Quality Results

4.1.1 Physical Tests

4.1.1.1 Turbidity

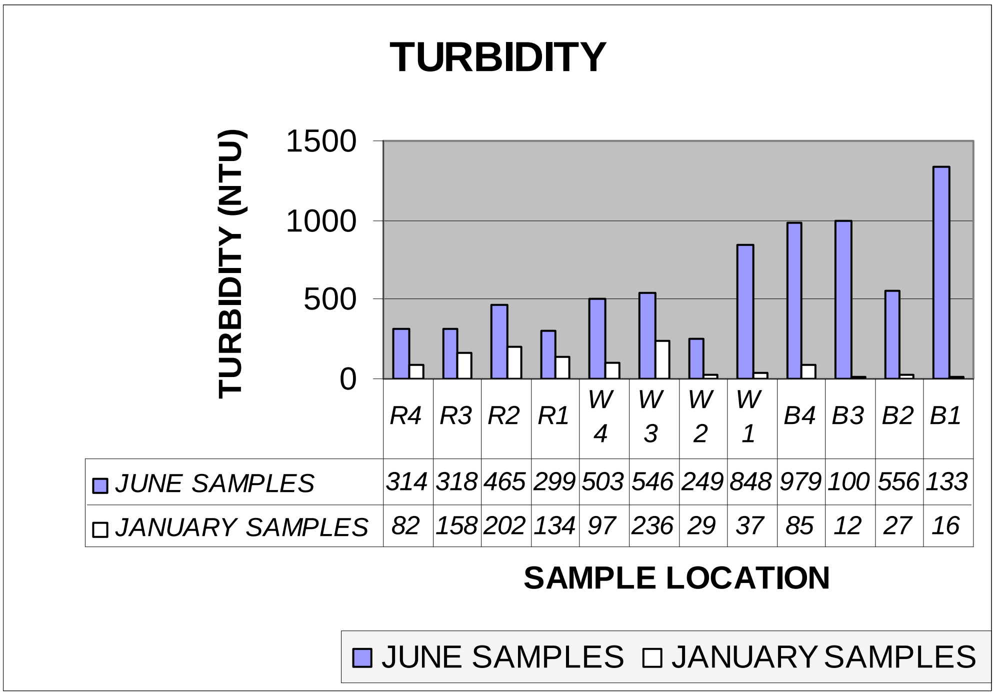


Figure 4.1 Turbidities of surface water samples

Previous studies for surface water found that[§] the range of turbidity of river Nile is 45 to 21040 NTU, Blue Nile turbidity range is 2 to 19575 NTU, and for White Nile is 55 to 22575 NTU. These high values which occur in the flood season are explained by the extent and nature of the development by man which include removal of vegetation by cutting forest and unmanaged agriculture that lead to excessive soil erosion particularly during the flood season so, produced high turbid water. (11)

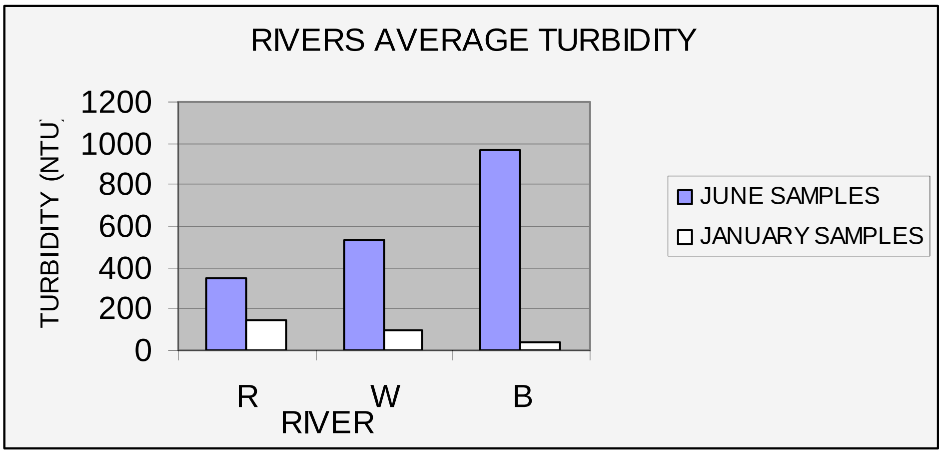


Figure 4.2 Average turbidities of rivers

§ Analyses of samples in the period 1997 to 2002

Turbidities values in June are higher in Blue Nile followed by White Nile and the lower value in river Nile, but in January the reverse happens.

4.4.2 Chemical tests

4.4.2.1 Dissolved oxygen

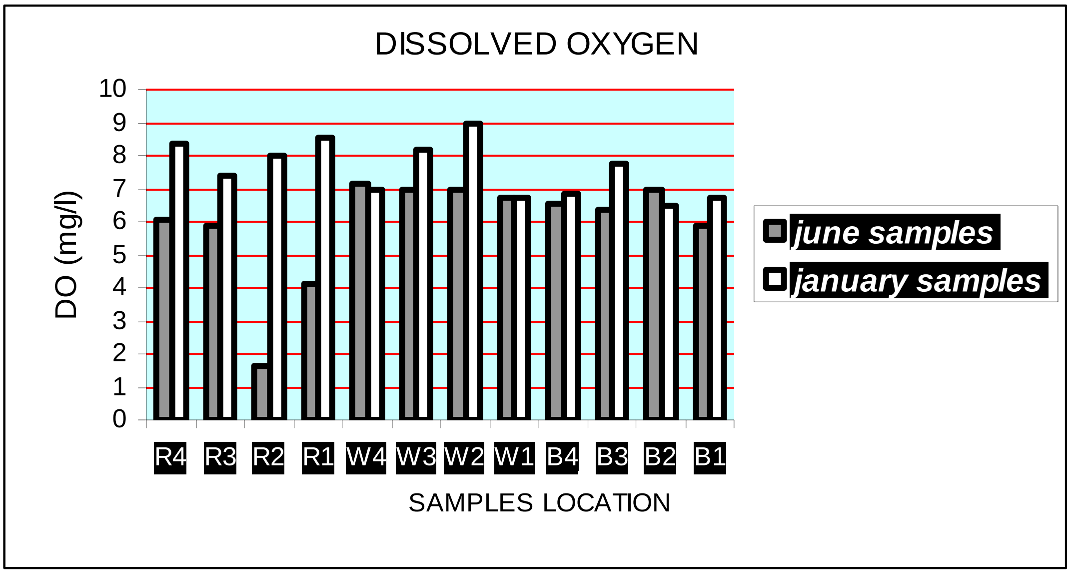


Figure 4.3 Dissolved Oxygen of surface water samples

Dissolved oxygen values is quite good (more than 5 mg/l)** except in R2 (almurada), this may happen because of the pollution due to the flowing of wastes of fishes cleaning in this location. This lower value not present in January because samples in January was taken early in morning before fishers start their fishes cleaning work.

The values of dissolved oxygen for the two periods are near together, except for R1 (national assembly) and R2 (almurada), this make the average DO for river Nile in study area in January is higher by approximately double of it's June value. Following figure shows that.

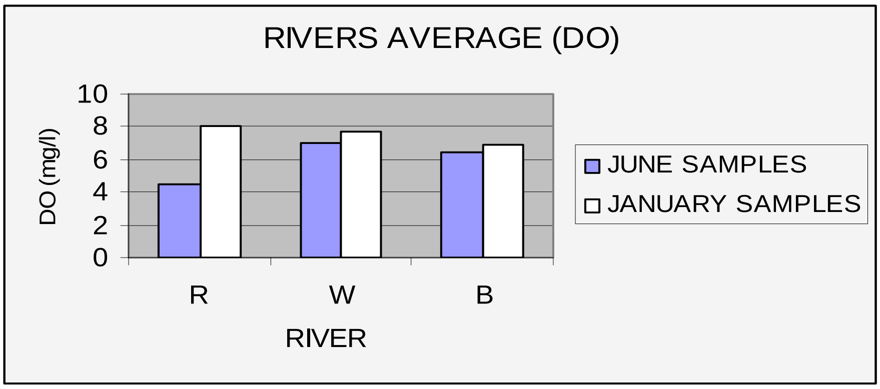
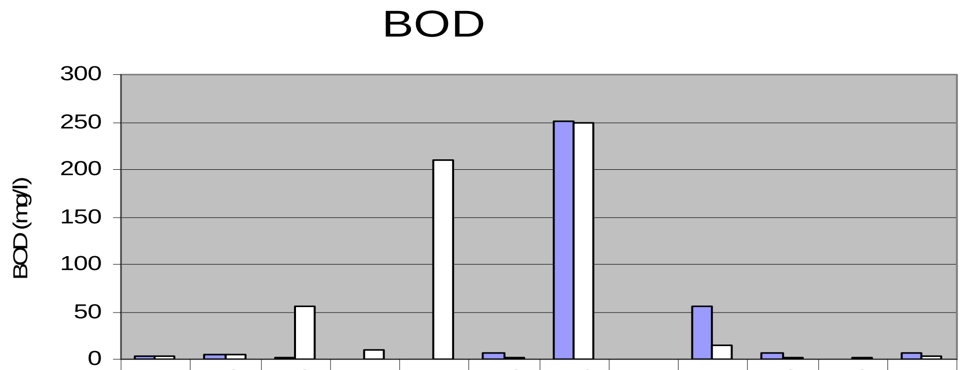


Figure 4.4 Average Dissolved Oxygen of rivers

** See chapter two

4.4.2.2 Biochemical Oxygen Demand

It is obvious that there is a high value of BOD in two locations: W2 (alshajra), and W4 (medical arm).



	R4	R3	R2	R1	W4	W3	W2	W1	B4	B3	B2	B1
JUNE	3,92	5,33	1,17	0,08		7,3	251	0	55	6	0	6
JANUARY	3,21	5,42	55,2	10	210	2,31	250	0,6	14,6	0,9	1,6	2,65

LOCATION

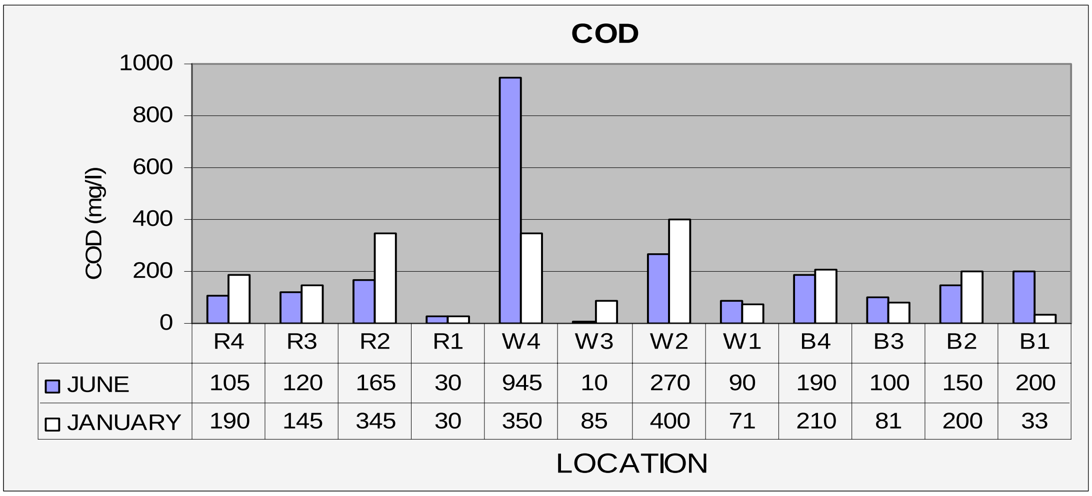
Figure 4.5 Biochemical Oxygen Demands of surface water samples

National pollutant discharge elimination system (NPDES)• specified limitation of BOD concentration in wastewater effluent, the arithmetic mean of the values for 24-hr composite samples†† collected in a period of 30 consecutive days must not exceed 30 mg/l, and the arithmetic mean of values in any period of 7 consecutive days must not exceed 45 mg/l. (2)

According to the above standards, (assuming that our value image of the arithmetic mean) BOD values illustrate that there are some problems in R2 (almurada) present in January, W2 (alshajra) present in both samples (June& January), W4 (medical arm) present in January sample which was repeated to confirm the result, but June sample of this point was not examined due to failure of the digital apparatus, and B4 (almugran) present in June sample.

•foundation in united state of America
†† See chapter two

4.4.2.3 Chemical Oxygen Demand



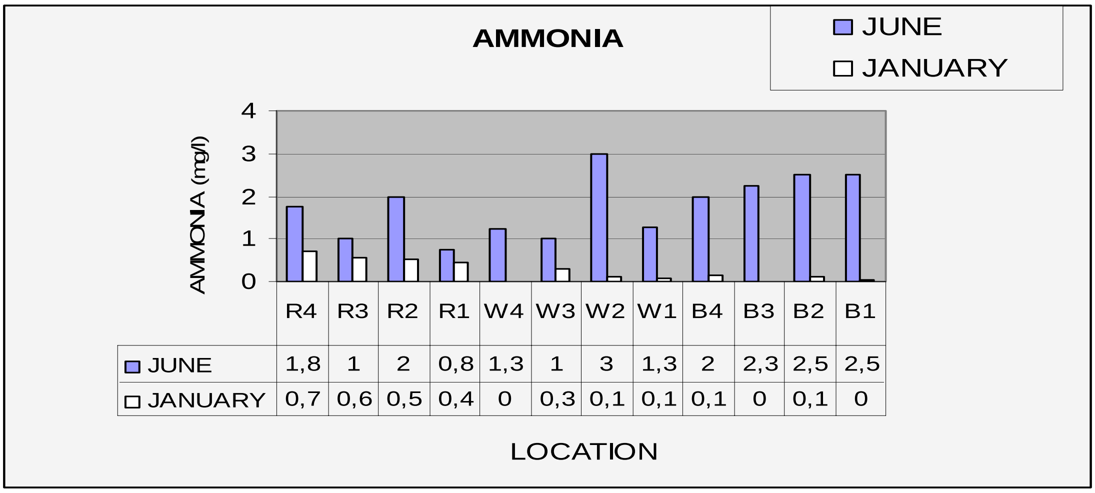
	R4	R3	R2	R1	W4	W3	W2	W1	B4	B3	B2	B1
JUNE	105	120	165	30	945	10	270	90	190	100	150	200
JANUARY	190	145	345	30	350	85	400	71	210	81	200	33

Figure 4.6 Chemical Oxygen Demands of surface water samples

The above values of COD enforce that notes which are noted in the BOD values.

4.4.2.4 Nitrogen

For ammonia nitrogen:



	R4	R3	R2	R1	W4	W3	W2	W1	B4	B3	B2	B1
JUNE	1,8	1	2	0,8	1,3	1	3	1,3	2	2,3	2,5	2,5
JANUARY	0,7	0,6	0,5	0,4	0	0,3	0,1	0,1	0,1	0	0,1	0

Figure 4.7 Ammonia of surface water samples

According to (WHO) guidelines ammonia toxicological effects are observed only at exposure above about 200 mg/kg of body weight. Because ammonia occur in drinking-water at concentration well bellow those at which toxic effects may occur, ammonia has been tabulated with chemicals for which guideline values have not been established.(8)

Natural levels of ammonia in ground and surface water are usually bellowing 0.2 mg/liter. Anaerobic ground waters may contain up to 3 mg/liter. Ammonia in water is an indicator of possible bacterial, sewage, and animal waste pollution. (8)

Samples analyses show that the minimum value of surface water ammonia concentration in June (0.8 mg/l) is equal to four times the usual value. In January samples, the values were normal, with slight increase in river Nile.

In other hand, ammonia has advantage in the water disinfection process; a monochloramine residual may have advantages over free chlorine residual. In water, ammonia and chlorine react to form monochloramine (NH_2Cl), dichloramine ($NHCl_2$) and nitrogen trichloride (NCl_3). The chloramines are less powerful disinfectants than free chlorine, and are therefore often used as a secondary rather than a primary disinfectant within the treatment plant. However, they do persist in distribution 24 Safe Piped Water (decay rates can be up to 20 times slower than free chlorine). Nitrogen trichloride produces a strong taste and odor at concentrations above 0.02 mg/l, whereas taste and odor thresholds for monochloramine are between 0.48 and 0.65 mg/l. High concentrations of dichloramine (> 0.15 mg/l) may produce tastes and odors. It is, therefore, important to control the disinfection process to produce a stable residual that is predominantly monochloramine. This requires evaluation of the water in question as a function of temperature, but normally a molar ratio of chlorine to ammonia of one and a pH value above seven is required.

Monochloramine is more effective than free chlorine at penetrating and inactivating organisms within biofilms, especially where corrosion products are present.

Treatment to produce a monochloramine residual does pose the risk of nitrite formation in the distribution system, especially in low-flow stagnant areas.

Bacteria on surfaces and in deposits may nitrify any slight excess of ammonia.

However, careful control of the chloramination process will prevent most nitrite problems. If nitrite does occur at certain locations, despite good control of the chloramination process, then the presence of internal pipe deposits at these locations should be investigated.‡‡

‡‡ http://www.who.int/water_sanitation_health/dwq/en/safepipedwater.pdf

4.4.2.5 Oil and grease

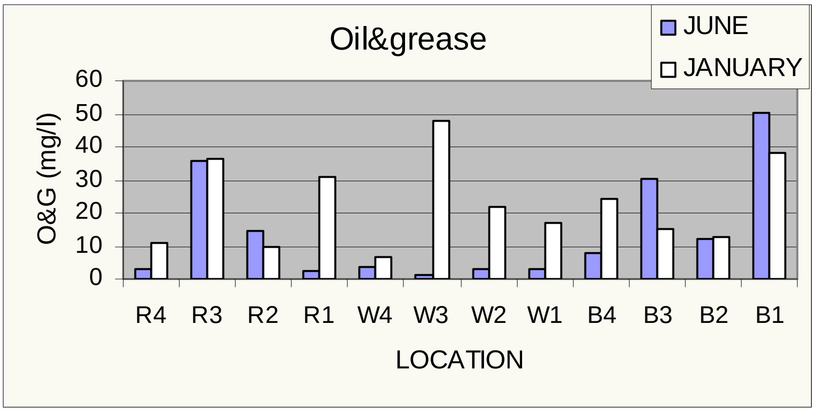


Figure 4.8 Oil and grease of surface water samples

Environmental protection agency (EPA)§§ established aquatic life quality criteria for water, for oil and grease EPA specified that "Surface waters shall be virtually free from floating nonpetroleum oils of vegetable or animal origin, as well as petroleum-derived oils"***.

Oil and grease concentration in municipal wastewater effluent, are limited by the National pollutant discharge elimination system (NPDES), naming: arithmetic mean must not exceed 10 mg/l for any period of 30 days or 20 mg/l for any period of 7 days. (2)

According to above standards, there is oil and grease pollution problem in many locations, this problem is obvious in January samples because of low of temperature. High concentration of oil and grease may explained by the activities in riverside (cars cleaning, fishes cleaning, pumps of red-brick kilns).

4.4.2.6 pH

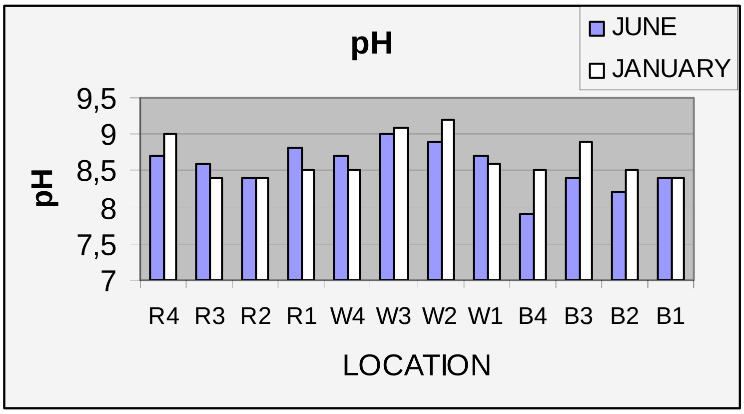


Figure 4.9 pH values of surface water samples

§§ Governmental agency in united state of America
*** http://www.epa.gov/waterscience/criteria/goldbook.pdf

There is no wide different between pH values of samples, all of them locate in the range of 7.9 to 9.2, average values of the rivers pH shown in following figure,

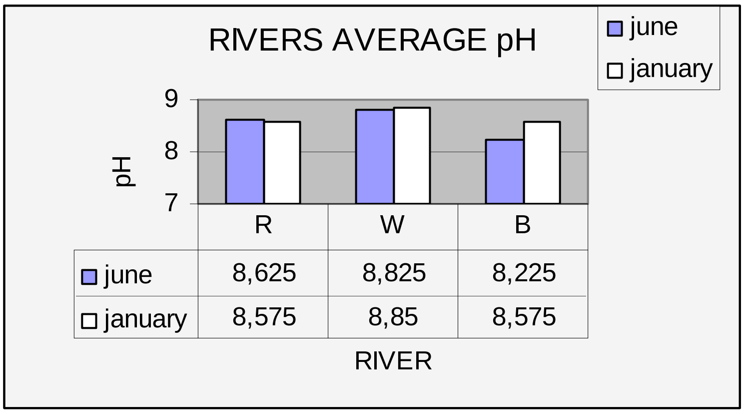


Figure 4.10 Averages pH for rivers

4.4.2.7 Total Dissolved Solid

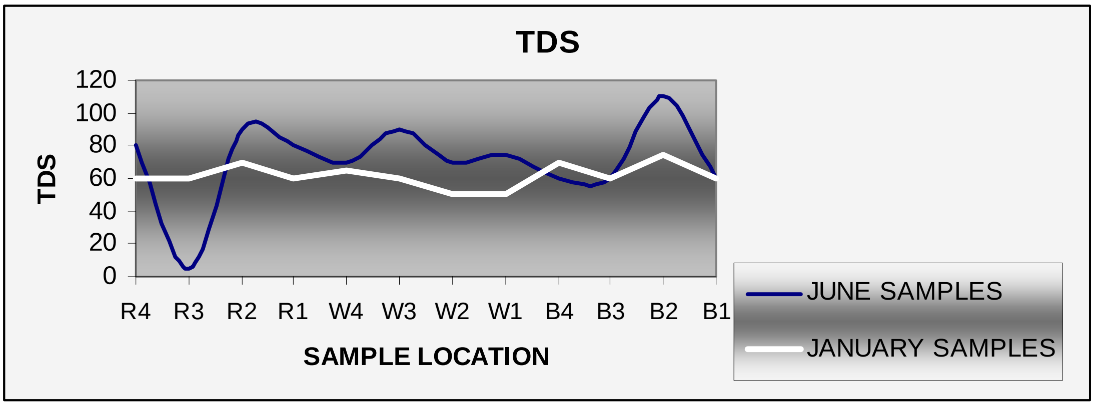


Figure 4.11 Total dissolved solid (TDS) of surface water samples

It is easily to note that the TDS values in June is higher than it's values in January, except in R3 (TV corp.) and B4 (almogran), but for Blue Nile the values for two points were not changed, these make the average TDS for Blue Nile in June and January approximately as the same, as shown in following figure.

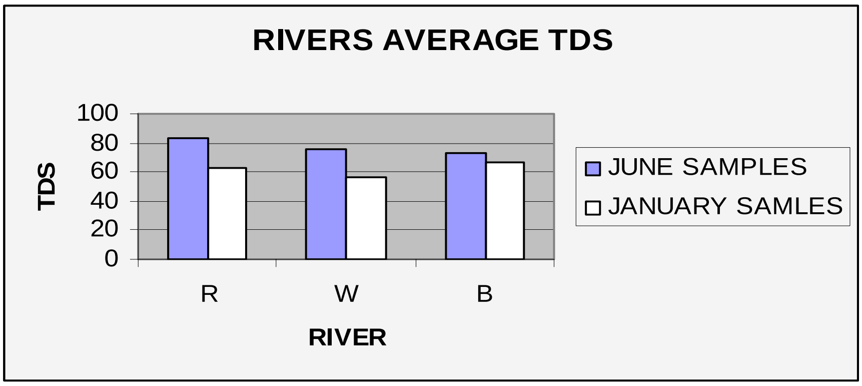


Figure 4.12 Average TDS for rivers

Criterion established by (EPA) specified that surface water quality limitation is "250 mg/L for chlorides and sulfates in domestic water supplies (welfare)"††† the samples TDS values are conformable this standard.

4.4.3 Biological tests

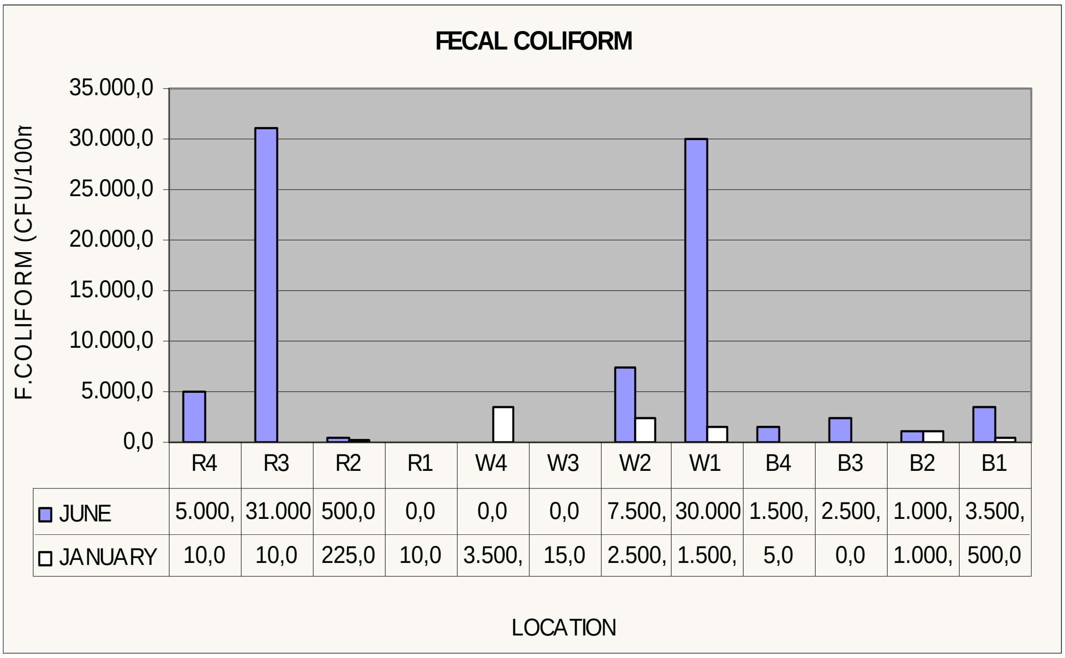


Figure 4.13 Fecal colifrom of surface water samples

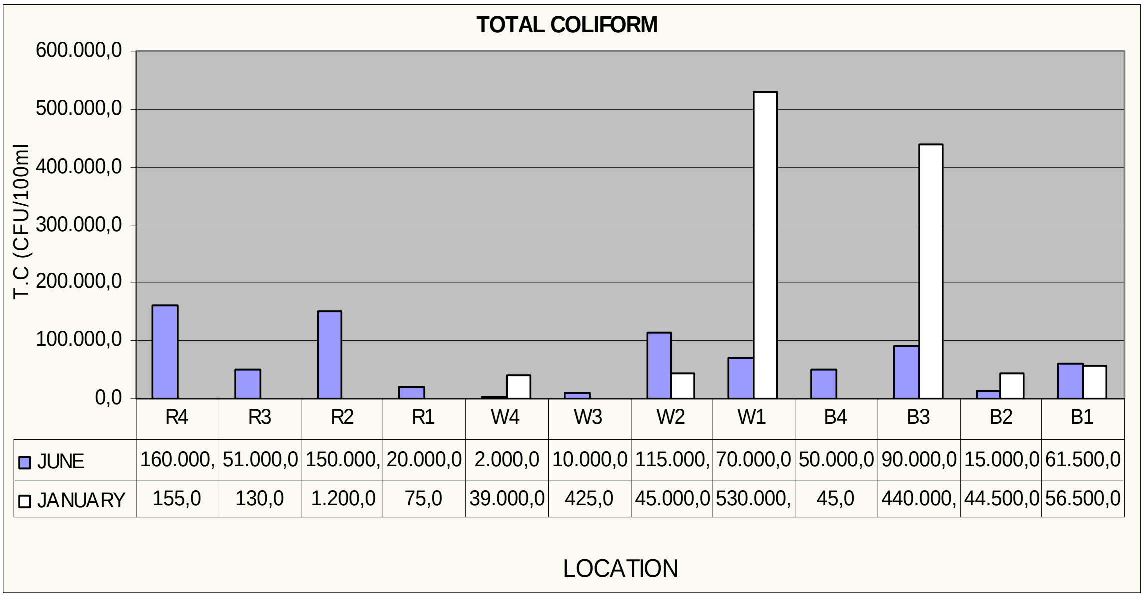


Figure 4.14 Total colifrom of surface water samples

The bacteria predominate completely in high organic streams under anaerobic conditions. The number of bacteria present under these conditions usually exceeds 10^7 or 10^8 per milliliter with a few well-adapted species. Thus it is that a few species of a

††† http://www.epa.gov/waterscience/criteria/goldbook.pdf

large number of microorganisms characterize the polluted stream, while a few microorganism of large number of species characterize the clean stream. (5)

Guidelines for recreational water environment are put by World Health Organization (WHO)[‡‡‡] explain that "Recreational waters generally contain a mixture of pathogenic and non-pathogenic microorganisms. These microorganisms may be derived from sewage effluents, the recreational population using the water (from defecation and/or shedding), livestock (cattle, sheep, etc.), industrial processes, farming activities, domestic animals (such as dogs) and wildlife. In addition, recreational waters may also contain free-living pathogenic microorganisms.These sources can include pathogenic organisms that cause gastrointestinal infections following ingestion or infections of the upper respiratory tract, ears, eyes, nasal cavity and skin"

Available evidence suggests that the most frequent adverse health outcome associated with exposure to faecally contaminated recreational water is enteric illness. Transmission of pathogens that can cause gastroenteritis is biologically plausible and is analogous to waterborne disease transmission in drinking-water, which is well documented.

Table 4.28 shows the WHO guidelines values for microbial quality of recreational water.

‡‡‡ http://www.who.int/water_sanitation_health/bathing/srwg1.pdf

Table 4.28 Guideline values for microbial quality of recreational waters[§§§]

TABLE 4.7. GUIDELINE VALUES FOR MICROBIAL QUALITY OF RECREATIONAL WATERS

95th percentile value of intestinal enterococci/100 ml (rounded values)	Basis of derivation	Estimated risk per exposure
≤40 A	This range is below the NOAEL in most epidemiological studies.	**<1% GI illness risk** **<0.3% AFRI risk** The upper 95th percentile value of 40/100 ml relates to an average probability of less than one case of gastroenteritis in every 100 exposures. The AFRI burden would be negligible.
41–200 B	The 200/100 ml value is above the threshold of illness transmission reported in most epidemiological studies that have attempted to define a NOAEL or LOAEL for GI illness and AFRI.	**1–5% GI illness risk** **0.3–1.9% AFRI risk** The upper 95th percentile value of 200/100 ml relates to an average probability of one case of gastroenteritis in 20 exposures. The AFRI illness rate at this upper value would be less than 19 per 1000 exposures, or less than approximately 1 in 50 exposures.
201–500 C	This range represents a substantial elevation in the probability of all adverse health outcomes for which dose–response data are available.	**5–10% GI illness risk** **1.9–3.9% AFRI risk** This range of 95th percentiles represents a probability of 1 in 10 to 1 in 20 of gastroenteritis for a single exposure. Exposures in this category also suggest a risk of AFRI in the range of 19–39 per 1000 exposures, or a range of approximately 1 in 50 to 1 in 25 exposures.
>500 D	Above this level, there may be a significant risk of high levels of minor illness transmission.	**>10% GI illness risk** **>3.9% AFRI risk** There is a greater than 10% chance of gastroenteritis per single exposure. The AFRI illness rate at the 95th percentile point of >500/100 ml would be greater than 39 per 1000 exposures, or greater than approximately 1 in 25 exposures.

[§§§] Notes:

1. Abbreviations used: A–D are the corresponding microbial water quality assessment categories used as part of the classification procedure; AFRI = acute febrile respiratory illness; GI = gastrointestinal; LOAEL = lowest-observed-adverse-effect level; NOAEL = no-observed-adverse-effect level.

4.5 Analysis and Discussion of Soakaway Wells Results

Selected locations of septic tank effluents samples were encoded as shown in chapter 3 (table 3.1).

4.5.1 Biochemical Oxygen Demand

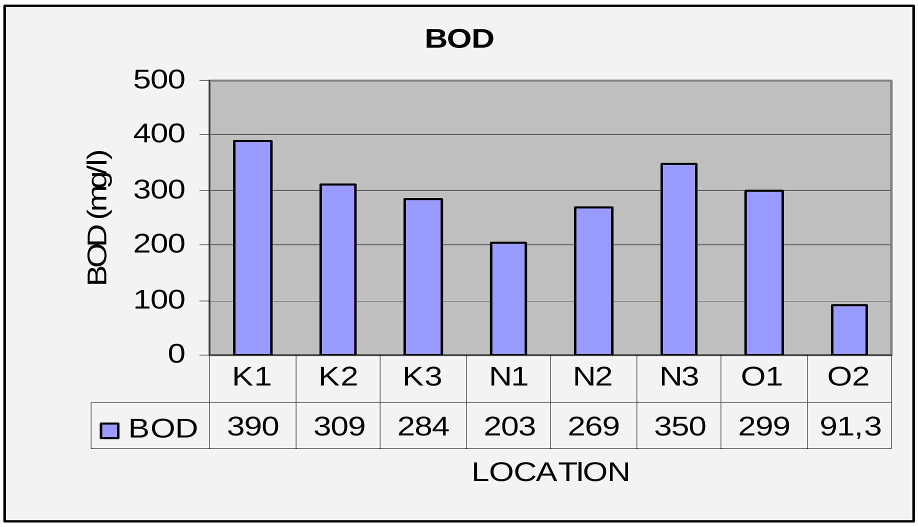


Figure 4.15 Biochemical Oxygen Demand of septic tank effluents samples

The average BOD of these samples = 274.4 mg/l

4.5.2 Chemical Oxygen Demand

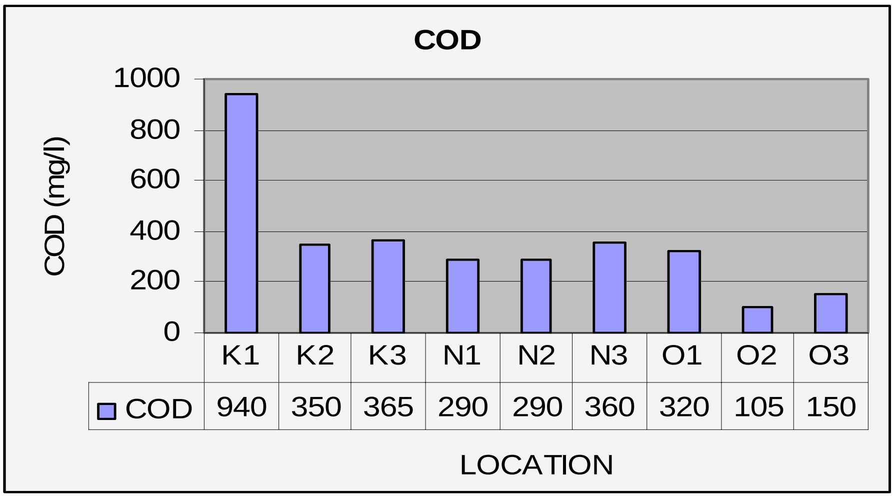


Figure 4.16 Chemical Oxygen Demands of septic tank effluents samples

Average value of COD = 352.2 mg/l

4.5.3 Ammonia nitrogen

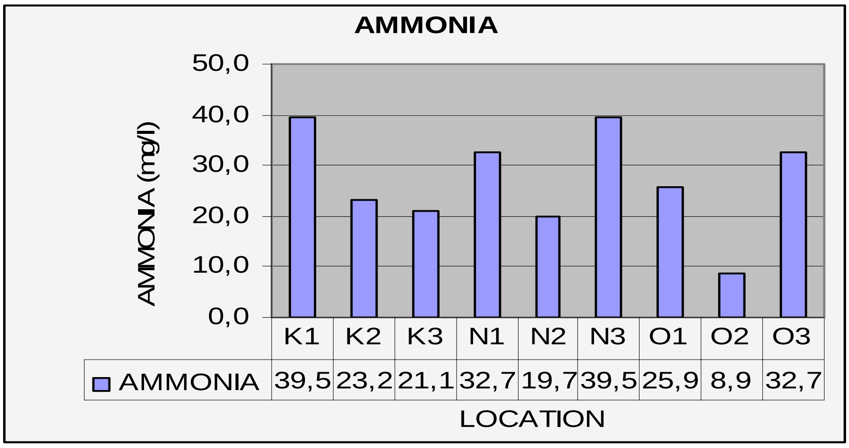


Figure 4.17 Ammonia of septic tank effluents samples

Average value of ammonia concentration = 27 mg/l

Presence of ammonia in high concentrations with absence of nitrate indicates that the pollution is fresh or occurring of bacterial denitrification which happens when organic matter (AH2) is oxidized and nitrate is used as a hydrogen accepter releasing nitrogen gas (2), as illustrated in following equation:

$$NO_3^- + AH_2 \longrightarrow A + H_2O + N_2$$

The above septic tank effluents samples results emphasis that using of wells to dispose septic tank effluents forms direct injection of pollutants into ground water, which is very risky to groundwater resources (IHP national committee of the Sudanese national commission for education, science & culture, 2000, vulnerability of groundwater resources of Sudan to pollution risks), the research revealed that the vertical migration of the contaminants is probable particularly in Khartoum and to lesser extent in Khartoum north. In Omdurman area the situation is better and the vertical migration is relatively less. In term of distances, the maximum vertical depths to which the contaminant would migrate in 20 years with concentration higher than the allowable are as follows: Khartoum 220 meter, Khartoum north 200-220 meter, and Omdurman 150-200 meter.(10)

4.6 Analysis and Discussion of Questionnaire Results

4.6.1 Family characteristics

Family characteristics in the questionnaire include: household monthly income, household work, number of family members, and household education level. The first two parameters have been neglected because of weak response. The mean family number of each locality and for all the state was illustrated in table 4.12, but the relationship between household education level and other parameters will be shown in next paragraphs.

4.6.2 Sanitation system used and its problems

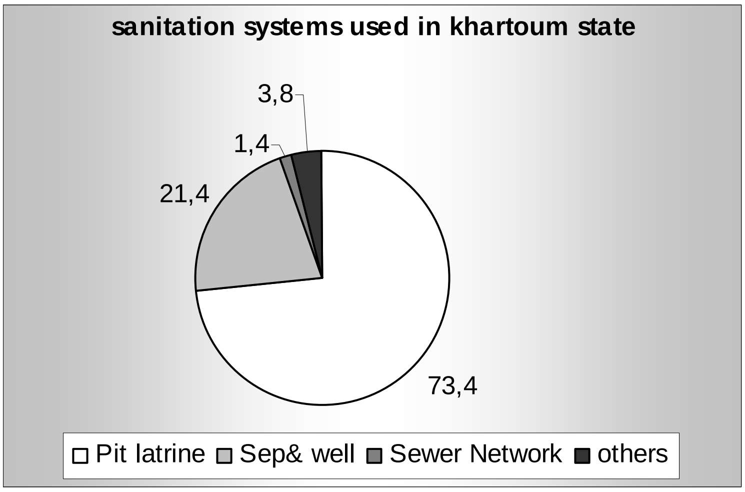


Figure 4.18 Sanitation systems have been used in kh. State

Others include open defecation (1.2%), neighbor (1.2%), mantling (0.4%), just septic tank (0.8%), and septic tank with soakaway (0.2%).

From above figure it is easy to note that pit latrine is the common sanitation system used in Khartoum state, as discussed in chapter two, pit latrine can be divided into two types: conventional pit latrine and ventilated improved pit latrine, these two types were founded in percentage as shown in figure 4.19 below.

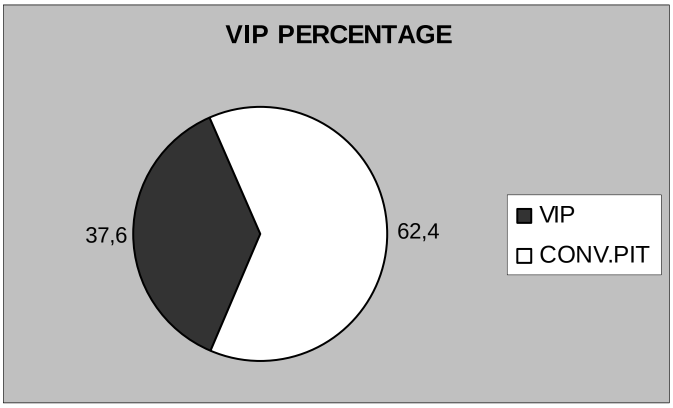


Figure 4.19 Conventional pit latrine and VIP percentage

Some conventional pit latrine users have a false thinking that when they use no shelter to pit latrine, they do not need to use ventilation pipe.

In some cases pit latrine is dug until reach water table, the percentage of these cases is illustrated in figure 4.20

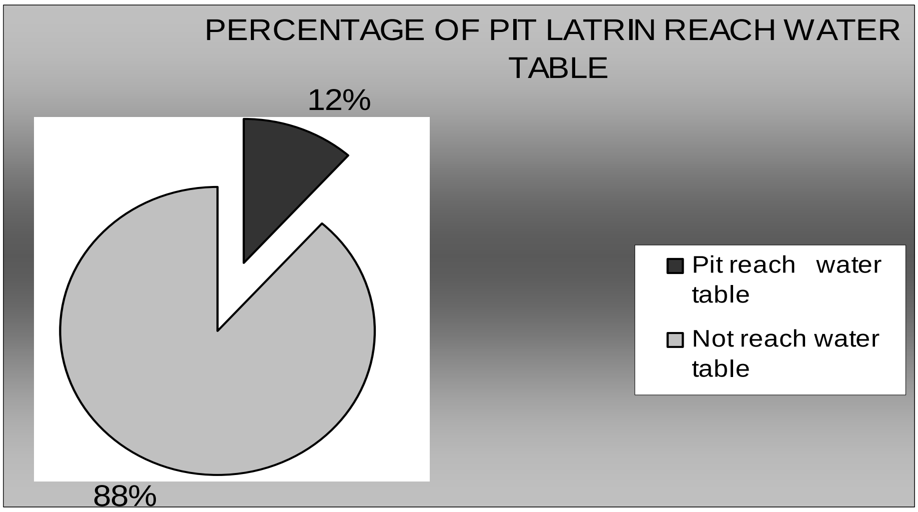


Figure 4.20 Percentage of pit latrines reach water table

The problems face pit latrine user could be classified into three categories: flies, insects, and odor. The percentage of these problems for the two types of pit latrine shown in figure 4.21

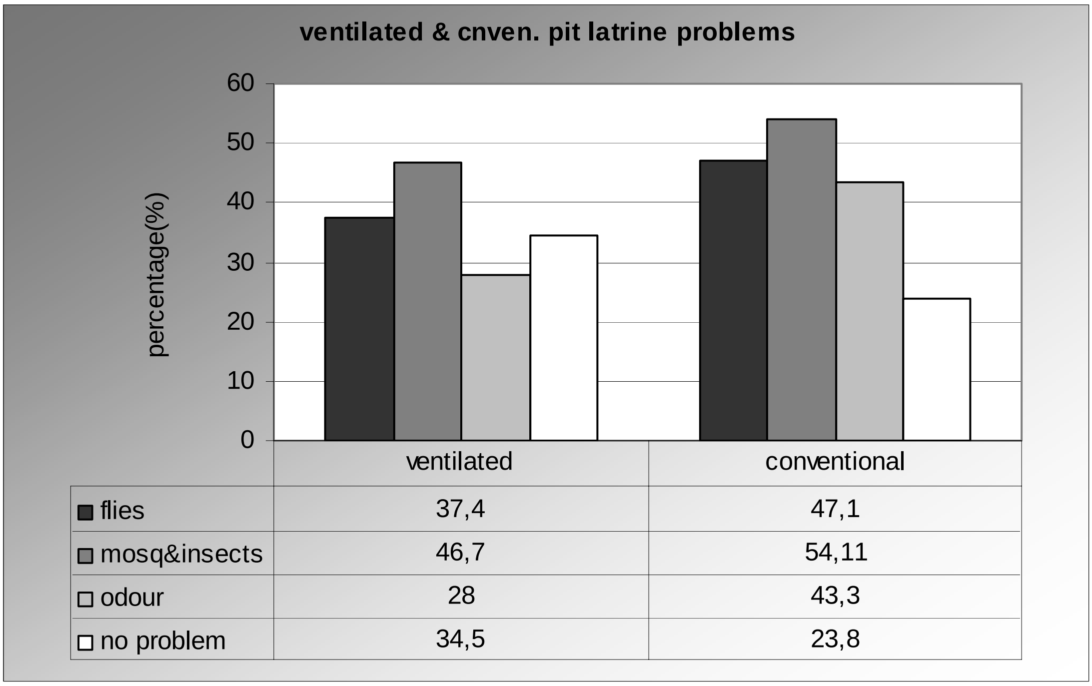


Figure 4.21 Ventilated and conventional pit latrine problems

Pit latrine problems has relationship with the pit content depth, this is illustrated in figure 4.22

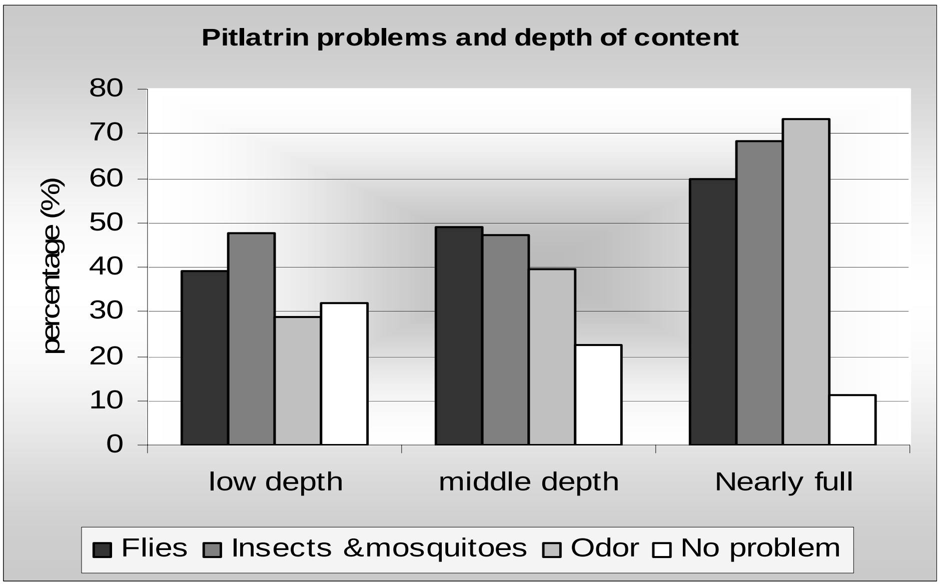
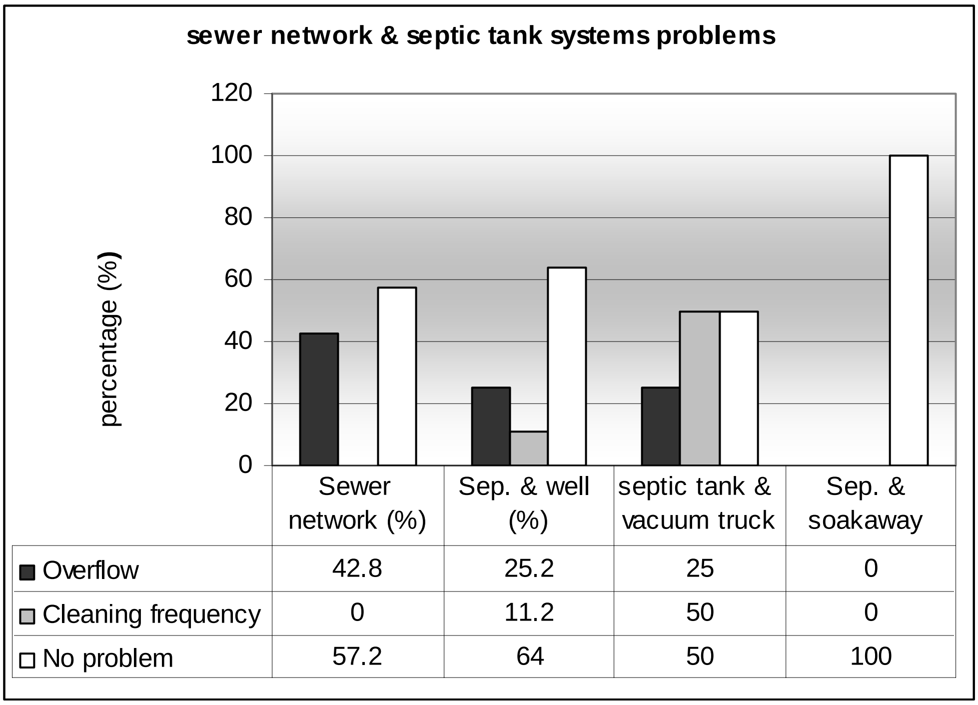


Figure 4.22 Pit latrine problems and the depth of content relationship

Systems are used to dispose sullage when using pit latrine is to spill sullage in the road, or using soakaway when the soil type is suitable. Although it has a bad environmental effect, the first type is the most common type.

Septic tanks systems and sewer network performing 22.4% and 1.4% of the sanitation systems have been used in Khartoum state respectively. The most problems faces these two types are: overflow and repetition of cleaning of the septic tanks in small period of time. The percentage of each one is illustrated in figure 4.23.



	Sewer network (%)	Sep. & well (%)	septic tank & vacuum truck	Sep. & soakaway
Overflow	42.8	25.2	25	0
Cleaning frequency	0	11.2	50	0
No problem	57.2	64	50	100

Figure 4.23 Sewer network and septic tanks systems problems

Table 4.13 shows that just 1.4% of the questionnaire fillers use sewer network. Those who use other sanitation systems were asked if they are interested in sewer network system, the result is illustrated in the following figure.

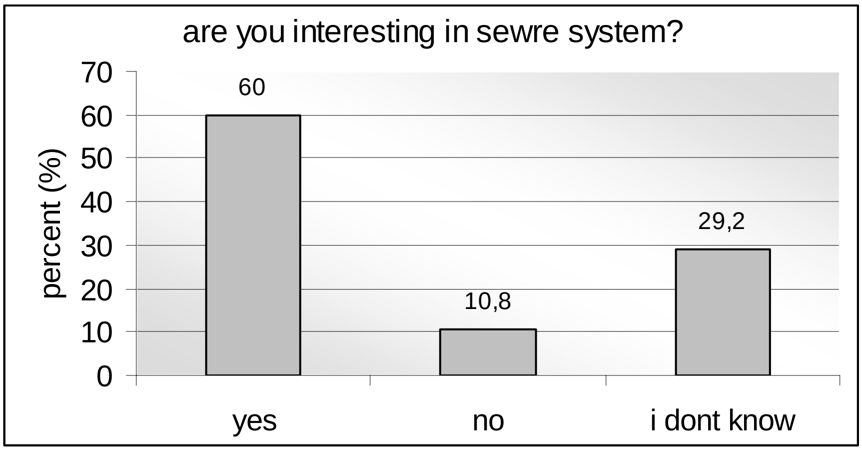


Figure 4.24 Interesting in sewer network.

What make 10.8 % reject sewer network system? Answer may classified in three reasons: "I don’t need it because I am satisfied from my sanitation system", Secondly: "because it will cost, and I can't pay", and the third reason: "because of the bad side effect of sewer network which appear in the current network". The percentage of each, illustrated in figure 4.25

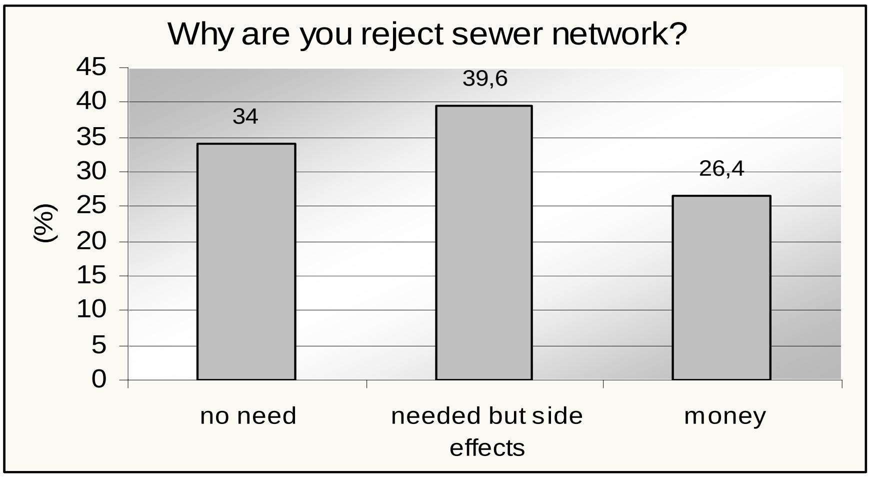


Figure 4.25 Reasons for reject sewer network.

Most of questionnaire fillers who reject sewer network (39.6%) explain their rejection by the bad serving of the current network; previous studies described this network Situation, and reporting that: the network is rather bad, the network's design age has ended more than 20 years ago, and condition of most of the pipes is not known; though must be corroded by now. Manhole's condition is not better. In addition to the adverse effects of methane gas and sulfur oxides, which results of warm sewage on its covers, lots of manholes are buried under the pavement asphalt. If not, holes and cracks on the covers are often visible. (12, 16)

4.6.3 Frequency of diseases infection

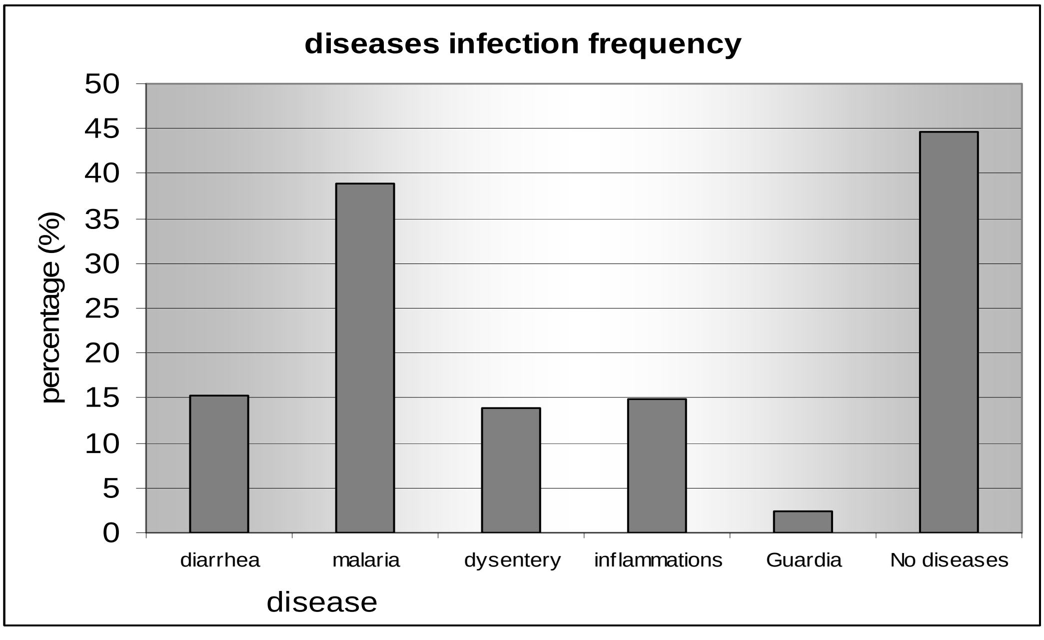


Figure 4.26 Diseases frequency in Kh. State

4.6.4 Source, quality, consumption, and cost of water

Water sources in study area are surface water, ground water, and mixed of the both surface and ground water. It is very difficult to classify each house in the study area. Most of the questionnaire fillers are not sure when answering the question of their water source.

According to annual report of towns Water Corporation of Khartoum state (2006), surface water formed about 47.4% of the total water outputting; the rest (52.6%) was the percentage of wells production. (13)

Water quality has been classified into seven classes: good, high turbidity, odor, slat, bad taste, color, and sediments, Figure 4.27 shows the percentage of each.

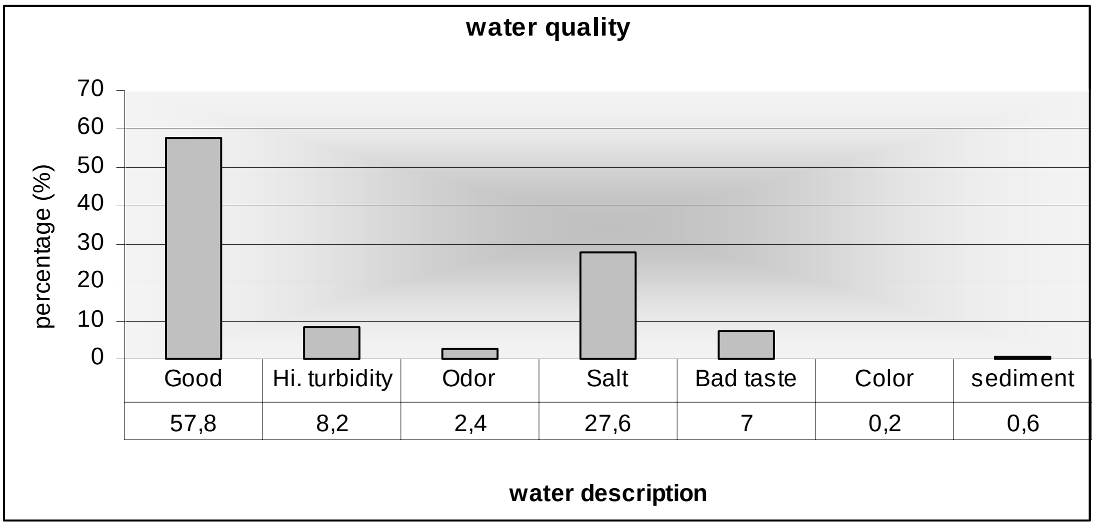


Figure 4.27 Water quality

It is expected that water quality impact on diseases infection, this relationship illustrated in figure 4.28

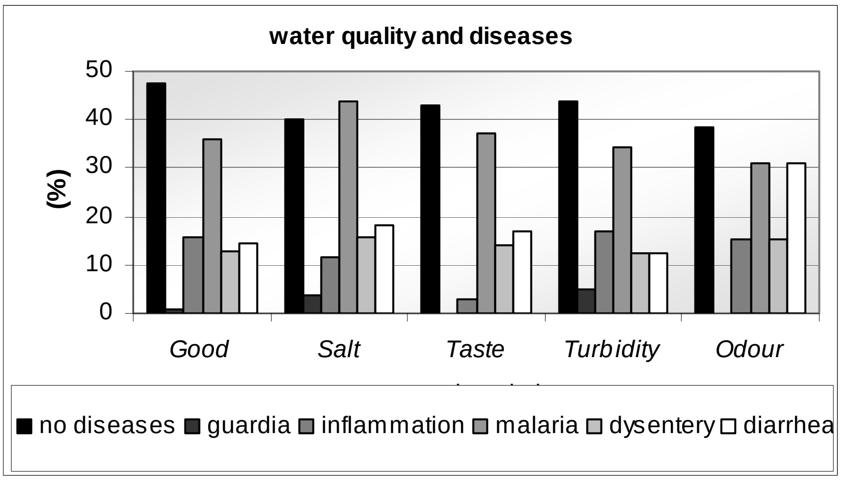


Figure 4.28 Water quality and diseases

Water consumption may be influenced by sanitation system used, education level, water cost or other parameter, some of suggested parameters have been analyzed and shown in following figures

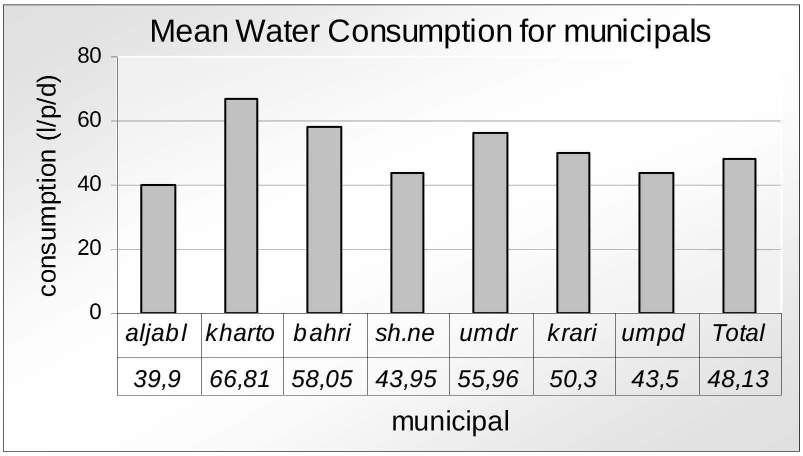


Figure 4.29 Water consumptions for each locality

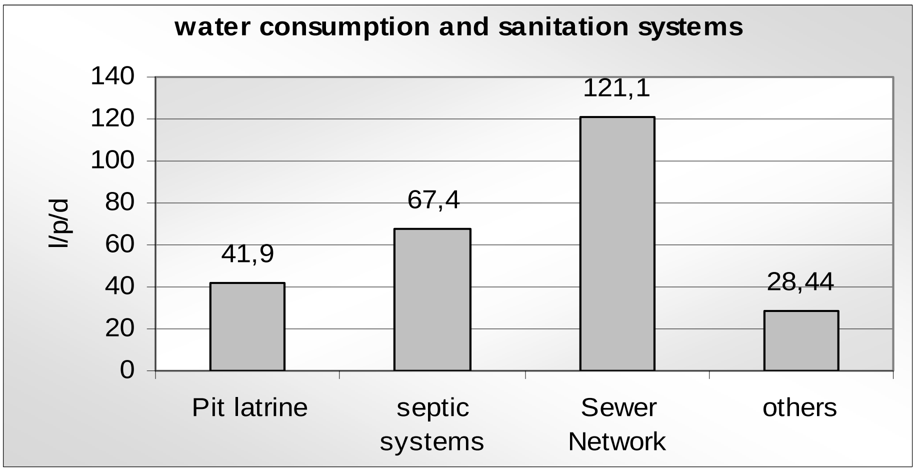


Figure 4.30 Water consumption and sanitation system

Septic systems include septic tank and wells, septic tank and soakaway, and septic tank and vacuum tanker. Other sanitation systems include open defecation, neighbor and mantling.

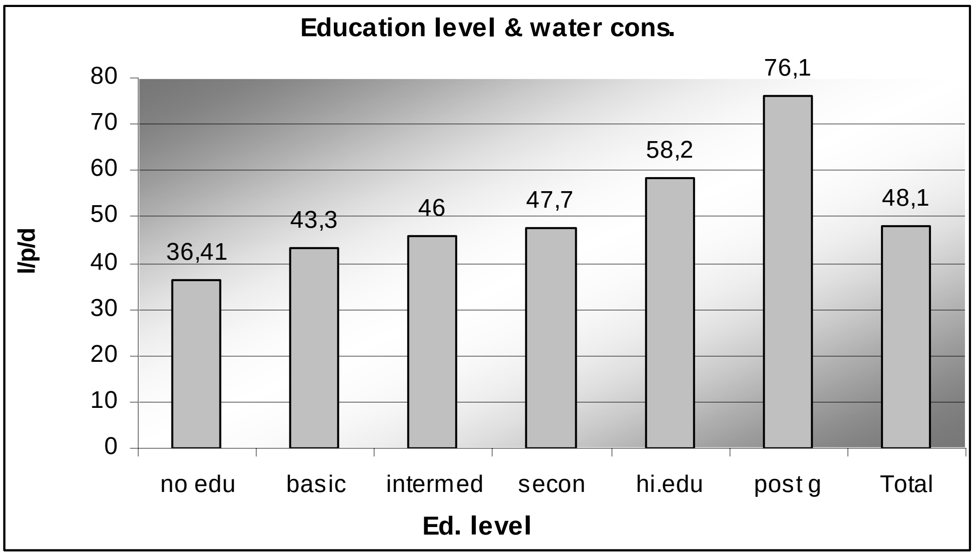


Figure 4.31 Water consumption and education level

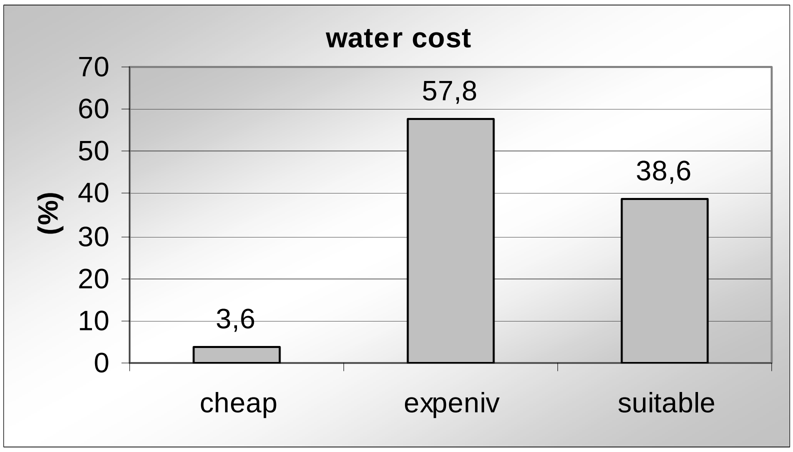


Figure 4.32 Water cost percentage

CHAPTER FIVE

CONCLUSION & RECOMMENDATIONS

CHAPTER FIVE

CONCLUSION & RECOMMENDATIONS

5.1 Conclusions

1. Surface water samples have shown high values of biochemical oxygen demand (BOD) in two locations in White Nile "alshajra" and near the medical arm. This result indicates that there is pollution problems in these two locations, the value of chemical oxygen demand (COD) and biological tests emphasize this inducing.
2. Oil and grease pollution has been founded in many locations; this pollution is a result of bad behaviors in the riverside such as fishes cleaning, trucks cleaning, and pumps of brick kilns fields.
3. The values of ammonia concentration in surface water sample above expected. This is obvious in June samples, but there is also slight increasing of ammonia concentration above the expected in river Nile in January.
4. Analyses of septic tank effluent samples have shown that there is a high value of biochemical oxygen demand which indicates the pollution risk; this inducing has been emphasized by the results of chemical oxygen demand.
5. High values of ammonia concentrations in septic tank effluents samples and the absence of nitrate, indicates fresh pollution or occurring of bacterial denitrification.
6. Most common sanitation system used in Khartoum state is pit latrine (73.4%), followed by septic tank and well (21.4%). The third one is group of some sanitation systems includes open defecation, using the neighbor pit, mantling, just septic tank, and septic tank with soakaway, this group forms 3.8%; lastly coming the Sewer network which forms just 1.4% of the sanitation systems are used in the study area.
7. 62.4% of pit latrines used in the study area are conventional pit latrine, just 37.6% have ventilation pipe, this may return to false idea that when you build the shelter without roof you do not need to use ventilation pipe.
8. 12% of pit latrines have been dug to the water table; this forms direct hazardousness to the groundwater quality.
9. Problems face pit latrine (odor, flies, insects), decrease by 10.7% when using ventilation pipe, this percentage can increase if the pipe is constructed

correctly (in sun direction, painted by black paint, net cover in the top of the pipe)

10. Problems face pit latrines have obvious link to the pit content level, the problems increase when the level of content increases.
11. 64% of septic tanks and well system are done properly, 25.2% suffer from overflow problem, and 11.2% suffer from improper design of the septic (septic needs to be cleaned in short period of time).
12. 42.8% of sewer network users suffer from overflow problem, and 57.2% satisfy from sewer network.
13. 60% of those who use sanitation systems other than sewer network are interested in sewer network, 10.8% reject it, and the rest (29.2%) have no answer.
14. 39.6% of those who reject sewer network explain their rejection according to the bad side effect of sewer network which appear in the current network. 34% because they are satisfied from their sanitation system and they are think there is no need to the network. 26.4% because of economical reasons.
15. According to consumer attitude to water quality, 57.8% of the water is good, 27.2% suffer from salt water, 8.2% complain from turbid water (specially in autumn season), 7% complain from strange taste, 2.4% complain from odor, and 0.2%, 0.6% note color, sediments in water respectively.
16. Average water consumption for pit latrine users is 42 liters per person per day, for septic systems (septic tank and wells, septic tank and soakaway, and septic tank and vacuum tanker) is 67.4 liter per person per day, for sewer network system is 121 liter per person per day, and for other sanitation systems (open defecation, neighbor latrine and mantling) is 28.4 liter per person per day.
17. There is an obvious link between education level and water consumption. The consumption by liter per person per day is 36.4, 43.3, 46, 47.7, 58.2, 76.1 for illiterate, basic, intermediate, secondary, high education, and post graduate education respectively.
18. Most water consumers think that water tariff is expensive (57.8%). 38.6% think it is suitable, and 3.6% think it is cheap.

5.2 Recommendations

1. Adopting of public awareness programs on the importance of proper sanitation facilities. This program may include awareness for importance of ventilation pipe, suggestion of new pit latrine types (Ventilated Improved Double-Pit Latrine, Reed odorless earth closet,….etc) and encouragement for septic tank systems without well (septic tank & soakaway, aqua privy, septic tank & vacuum tanker).
2. Establishing coordinating body for water supply and sanitation programs.
3. Instituting a fund to help people especially in rural areas to construct their proper sanitation systems ever as private or public sanitation facility. This help should be economical and technological.
4. Establishing surface and ground water monitoring program. The monitoring contains biological, chemical, and physical quality, to prevent water pollution and to ensure that the characteristics of water are founded in standard zone.
5. Further studies should be made on the related topics in the study area such as sullage disposal systems assessment.

References:

1- Basak, N. N., *Environmental Engineering*, 1st Ed, Tata McGraw-hill, New Delhi, 2003

2- Hammer, M. J., and Hammer J. *M., Water and wastewater technology*,4th Ed, prentice-hall of India, New Delhi, 2004

3- John, M. K., Julius, D. A., Mara, D. D., and Charles G. G., *Appropriate Technology For Water Supply And Sanitation- A planners guide*, 1st Ed. International bank for reconstruction and development, 1980

4- Mara, D. Duncan, *Appropriate Technology for Water Supply and Sanitation-Sanitation alternative for law-income communities*. 1st Ed. International bank for reconstruction and development, 1982

5- McKinney, R. E. *Microbiology for Sanitary Engineers*, 1st Ed, McGraw-hill, New York 1962

6- Metcalf & eddy, ink. *Wastewater engineering treatment and reuse*, 4th Ed, McGraw-Hill, New York, 2003

7- Nathanson, J. A., *Basic Environmental Technology*, Prentice-Hall, New Delhi, 4th Ed, 2004

8- WHO, *Guidelines for drinking-water quality*, 2nd Ed, vol 1, world health organization, Amman, Jordan 1993

9- Pacey, A., *Sanitation In Developing Countries*, 1st Ed. ELBS and John wiley & sons,1981

10- Abaker, Elhadi Omer, *Interaction of water supply & excreta disposal technology in Omdurman province, althowra locality*. M. Sc thesis, U of K, 2001

11- Ahmed, Nada Ibrahim, *Assessment of A water Treatment Plant (Case Study Mogran Water Works at Flood Seasons).* M. Sc. thesis in U of K, 2004

12- Mahgoub, Samar, and others, *Environmental Impact Assessment of Sanitation Facilities (Case Study: Khartoum State)*, partial B. Sc thesis, U of K, 2000

13- *عبد الماجد، عصام محمد*.، العاقب، عبدالرحمن أحمد.، الدرديري،الطاهر محمد.، الجزولي، التيجاني اسماعيل.، *الفضلات السائلة*، دار جامعة السودان للطباعة والنشر والتوزيع، الخرطوم، 2000

14- *تقرير هيئة مياه المدن*- ولاية الخرطوم للعام 2006

15- مجموعة عمل، *ورقة البيئة والسياحة*، اللجنة الوزارية العليا لدراسة تطوير مركز الخرطوم؛ سبتمبر 1999

16- مجموعة عمل، *ورقة البنيات التحتية*، اللجنة الوزارية العليا لدراسة تطوير مركز الخرطوم، سبتمبر 1999

17- http://www.khartoumstate.gov.sd/ (website of Khartoum state government)

18- Links from World Health Organization website

- http://www.who.int/medicines_technologies/human_rights/en/
- http://www.who.int/water_sanitation_health/factsfigures2005.pdf
- http://www.who.int/water_sanitation_health/dwq/en/safepipedwatr.pdf
- http://www.who.int/water_sanitation_health/bathing/srwg1.pdf

19- Link from Environmental Protection Agency website:

- http://www.epa.gov/waterscience/criteria/goldbook.pdf

20- Link from Federal Ministry of Health website:

- http://www.childinfo.org/MICS2/newreports/sudan1/FianalMICSSudan.pdf

Appendix

Questionnaire about Sanitation Systems in Khartoum State